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The Fourth World Power Conference

FROM July 10th to 15th the fourth plenary meeting of the World Power Conference was held in London. The World Power Conference is an international organisation whose purpose it is to consider how best to utilize, nationally and internationally, the world's resources of fuel and power. It was founded on the initiative of the late D. N. Dunlop, a founder of the Electrical Research Association and the Electrical Development Association, and director of BEAMA from 1917 until 1935, and it was in London that the First World Power Conference took place in 1924.

The Conference is a federation of national committees made up, in general, of Government representatives as well as representatives of industry and science, and of trade organisations. At present, there are about 40 such national committees in existence. Plenary meetings are normally held at intervals of six years, and sectional meetings may be held in the intervening period. Compared with the plenary meetings, these deal with more limited subjects within the framework of the general objects of the Conference, as, for instance, "Fuel Economy," which was the subject of the first post-war sectional meeting held at The Hague in 1947; "The Use of Electricity in Agriculture" and "Co-ordination of the Development of Industries and the Development of Power Resources" will be the subjects of the next sectional meeting to be held in New Delhi in 1951.

It had been expected that the plenary meeting which took place in London this year would be of particular interest, as it was the first conference after a war which had stimulated so many technical developments and brought about social changes, and as there had been an interval of 14 years since the last conference, held in Washington in 1936 under the auspices of the late President Roosevelt. There had also been no doubt that the standard of the papers submitted to the Fourth Conference would in all respects be as high as that of the preceding three, and that the discussions would be at the same high level and the attendance as distinguished and as representative. Moreover, it was confidently anticipated that old friendships would be renewed and new friendships made, although after an interval of so many years, there were bound to be only too many which could no longer be renewed but only remembered.

Events have proved the Fourth World Power Conference to have come up to expectations. It was a very interesting and gratifying experience to study the papers submitted and to listen to the many animated discussions; still more, it was time well spent to compare them with those of fourteen years ago. Already familiar topics came under review again: the evaluation of the power resources of various countries, the mercury turbine, oil resources and the utilization of coal and, in particular, peat and low-quality coal, the latter being a problem of ever growing importance. A further subject to come under discussion was the economies obtainable by the use of higher steam temperatures, a temperature of 1200° F already being envisaged. Still more important, there was an impressive number of new subjects competing for the attention of the delegates and attracting many even of those not directly concerned; wind-power, next to water power, perhaps the first source of energy ever used by mankind, has staged a spectacular come-back in the last few years; the heat pump; underground gasification of coal; the gas turbine as a power unit for locomotion and as prime mover for electricity generation. Utilization of the temperature difference between the deep and surface waters of the sea, although a subject once shelved, reappeared on the scene. Most of all, however, it was the release and utilization of nuclear energy which captivated the interest and imagination of all and which, perhaps unnoticed, had impressed its work on the Conference even before the latter had begun.

The wealth of specialist and technical knowledge presented was impressive enough to convince anybody, if indeed there had been any need to, that the dissemination and interchange of such knowledge is not only a worthy aim, but has become a necessity in our age, and that the World Power Conference has been meritoriously contributing to the fulfilment of this huge task. A no less important achievement consisted in demonstrating to the World that science and technology are travelling in the same direction everywhere, and exceedingly fast at that. By this demonstration the Fourth World Power Conference has thrown out a challenge to mankind to rally at last and to use the mighty resources put at our disposal by Nature and by the indefatigable work of men like those who attended the last meeting, to promote our own happiness in a peaceful world.

SWITZERLAND

New Principles for Commutator Design and Manufacture

By F. L. LAUB. (From *Bulletin de l'Association Suisse des Electriciens*, Vol. 40, No. 25, 1949, pp. 988-1001, 8 illustrations.)

With the principles set forth in this article, it should be possible to build commutators which will retain their compactness even under unfavourable working conditions. The practical conclusions arrived at are based on an analysis of the elastic deformations of the main commutator components, and formulae are derived for determining the mechanical and thermal forces involved. The first instalment of this article was published last month and the last part will follow in our September issue.

SEASONING

IT is worth while considering the stresses and permanent deformations obtained with the "seasoning" process. During the baking period, the copper bars expand more in the longitudinal direction than the iron commutator hub, owing to their higher expansion coefficient. Although the resulting bending of the bars is only an elastic deformation, it increases the diameter at the centre of the bulge and correspondingly reduces the flank pressures, so that the permanent deformation required is incomplete or even non-existent. Thus, after cooling and tightening, the bulge in the commutator surface will not disappear completely, nor will the "seasoning effect" in the centre portion of the commutator be the same as at its ends near the Vee rings. Under unfavourable conditions, with short or very strong tightening bolts, permanent deformations of the dovetail end and of the Vee rings can be the result of this treatment.

In an interesting report on commutators of locomotive motors, C. Bodmer* describes a commutator of 580 mm outer diameter and a bar length of 210 mm, in which the Vee rings had expanded so considerably that the diameter of the Vee edge had increased by 1·04 mm. Bodmer attributes these unusually large deformations to the use of too many tightening screws of large diameter, and to excessive tightening during manufacture. The bolts were also unusually short. Bodmer further mentions that satisfactory results were obtained with other locomotive commutators by reducing the cross-section of the tightening screws to 40 per cent of its original value. These facts bear out the remarks made above regarding the disadvantages of the seasoning process.

Thermal expansion of the bars occurs both in the longitudinal and the radial directions. The longitudinal expansion results in a tensile load on the tightening bolts, whereas the transverse expansion causes the dovetails to tend to open out the Vee rings. Thus, if the bolts are not excessively heavy, but can deform elastically under the tensile loads due to longitudinal expansion of the bars, it is possible to avoid the bulging of the bars and Vee ring distortion. This explains why the reduction of the tightening bolt cross-section was so successful, since locomotive type commutators frequently have to sustain temperatures above 100° C.

In the seasoning process, the temperatures are even higher, and are generally about 130-150° C. If the tightening bolts yield during this process to a practically appreciable extent, the seasoning effect is not obtained. Therefore, a further objection to the seasoning method is that it necessitates a non-elastic and hence incorrect construction of the commutator. The process not only has a non-uniform effect but is also very difficult to control. Permanent compactness of a commutator depends directly on the elasticity of its component parts, since completely free thermal expansion is impossible. A resumption of the original shape can only be obtained by means of the elastic stresses existing in these component parts. It is, therefore, contrary to the achievement of the desired result to damage the crystalline structure of the copper and mica by permanent deformations during manufacture.

*C. BODMER: Material utilisation in the construction of electrical locomotives. *Bull. Assoc. Suisse Electr.*, Vol. 33, 1942, No. 24, pp. 700-708.

BAR FINISHING

The flank pressure $p_i = 95{\cdot}58$ kg/cm² determined in the previous example† can be regarded as normal, and as there is no reason for choosing for p_i a value much above 1–2 kg/cm², the mean flank pressure is 48·79 kg/cm². However, if it is considered advisable to reduce this value for manufacturing reasons, then p_i could be reduced to 91·77 kg/cm² by using micanite separators with a thickness $s = 0{\cdot}12$ cm instead of 0·10 cm. This slight reduction in stress is obtained at the cost of an increase of 1·35 cm in the commutator diameter. As the phlogopite chosen is already the softest quality available, the only means of reducing the flank pressure still further is by decreasing the excess in thickness Δ.

This reduction of the excess thickness Δ requires an extremely high manufacturing accuracy, which is not achievable by the usual methods of manufacture. A simple method, however, is to use a precision surface grinding machine to grind the bars already cut to the required length, in order to obtain the desired taper angle. This machine should include a clamping table which can be inclined to the correct angle with an accuracy up to the 5th decimal place for the sine or tangent, the tolerance being only within the 6th decimal. This tolerance can be maintained by means of two adjustable wedges with slopes of 1 : 100 and 1 : 1000, respectively, for a range of angles between 50′ and 6°, corresponding to numbers of bars between 432 and 60. The most effective arrangement is to have the transverse motion of the grinding wheel spindle and its axial control motion performed by the two carriages of the grinding motor, while the clamping table with the bars remains stationary.

As the quantity of copper to be removed is extremely small (less than 1/40 mm according to British standards, or up to 1/10 mm in countries where the limits are not specified), this operation only requires little time and is, therefore, inexpensive. Small commutators of less than 15 cm diameter should only be included in these considerations in exceptional cases, but for larger size commutators, by eliminating the cost of the seasoning process, manufacturers will find it amply justified to cover the additional expense required by the copper bar suppliers for the precision grinding of the bars.

TRANSVERSE (TANGENTIAL) THERMAL EXPANSION OF THE BARS

Equations (II) and (IIa)† show how the radial distribution of flank pressure is affected by taper angle inaccuracy. This inaccuracy is due to the excess thickness Δ, and also to temporary variations caused by thermal transverse or tangential expansion. This thermal expansion will now be assessed so as to obtain a useful criterion for the determination of the bar profile.

Let Δb_x = thermal expansion in the tangential direction; Δt = temperature rise in the running surface; $k\Delta t$ = temperature increase at the inner commutator surface, where k is less than unity, so that $1-k$ = percentage temperature drop; furthermore, let h_o = height of bar at ambient temperature, and h_t = bar height for temperature conditions defined by Δt and $k\Delta t$; the linear expansion coefficient for hard-drawn copper will be taken as $\alpha = 0{\cdot}000017$.

†See first instalment of this article, July, 1950.

Assuming that the temperature drop in the bar is linear in the radial direction, we can write

$$h_t = h_o\,[1 + \tfrac{1}{2}\,(\alpha \Delta t + k \Delta t)]$$

The transverse expansion Δb_x at any intermediate height h_x (measured from the inner commutator surface) is given by

$$\Delta b_x = \alpha\,[k\Delta t + (1 - k)\,(h_x/h_t)\,\Delta t] \times [b_i + (b_e - b_i)\,(h_x/h_t)] \quad .. \quad .. \quad \text{(III)}$$

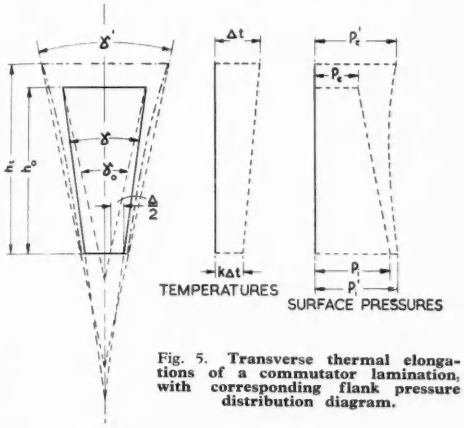

Fig. 5. Transverse thermal elongations of a commutator lamination, with corresponding flank pressure distribution diagram.

This is a quadratic equation in h_x and is thus represented by the chain-dotted curves in Fig. 5, indicating the concave contour of the bar flanks due to thermal expansion. The concave effect at the height $h_x = h_t/2$, measured perpendicularly to the plane of symmetry of the bar, is then

$$\Delta b_m = \alpha \Delta t\,(1 + k)\,(b_e + b_i)/8.$$

The flank pressure diagram of Fig. 5 shows the condition which is required in order to prevent p_e increasing to a value greater than p_i, that is, to avoid conditions represented in Fig. 2a. The requirement is that the angle γ', formed by the edges of the expanded profile, should not be greater than the pitch angle $\gamma_o = 360°/K$. If this condition is maintained, Δ cannot become negative, and p_e cannot exceed p_i. We thus have

$$\gamma' \leq \gamma_o \text{ or } \tan(\gamma'/2) \leq \tan(\gamma_o/2)$$

and this is equivalent to

$$\frac{b_e(1 + \alpha\,\Delta t) - b_i\,(1 + \alpha\,k\Delta t)}{2\,h_o\,[1 + \tfrac{1}{2}\,\alpha\,\Delta t\,(1 + k)]} \leq (b_e - b_i + \Delta)/(2\,h_o)$$

so that

$$\Delta \geq (b_e + b_i)\,(1 - k) \,/\, [1 + k + (2/\alpha\Delta t)] \quad .. \quad \text{(IV)}$$

This equation can be further simplified by inserting the maximum values for Δt permitted by standard regulations for each type of machine considered. In the following examples the rules proposed for bar section design are based on British specifications.

B.S. 168/1926 (Industrial motors and generators with class A insulation) gives 45° C as the maximum permissible temperature increase in the commutator running surface for all machines which are not completely enclosed, and 55° C for completely enclosed machines. As, however, local temperature differences are considerably greater in machines with through-draught ventilation, only ventilated machines will be dealt with. Substituting 45° C for Δt in eq. (IV) we obtain $2/(\alpha\Delta t) = 2614{\cdot}4$, and $1 + k + 2614{\cdot}4 \simeq 2616$, so that on the basis of B.S. 168/1926 eq. (IV) becomes:

$$\Delta \geq 3{\cdot}823 \times 10^{-4} \times (b_e + b_i)\,(1 - k) \quad \text{(V)}$$

When the value of Δt is already given, the allowable percentage temperature drop in the bar is determined by

$$(1 - k) \leq 2616\,\Delta/(b_e + b_i) \text{ per cent} \quad .. \quad \text{(VI)}$$

and the temperature drop in °C should not exceed

$$(\Delta t - k\Delta t) \leq 2616\,\Delta t \times \Delta/(b_e + b_i) \quad .. \quad \text{(VII)}$$

For traction motors used on rail or road vehicles, the maximum value of Δt is determined by B.S. 173/1928, which specifies $\Delta t = 85°$ C for permanent rating, and 90° C for one-hour rating. Accordingly, we obtain:

Permanent rating:

$$\Delta \geq 7{\cdot}215 \times 10^{-4} \times (b_e + b_i)\,(1 - k)$$
$$(1 - k) \leq 1386\Delta/b_e + b_i)$$
$$(\Delta t - k\Delta t) \leq 1386\Delta t\Delta/(b_e + b_i)$$

One-hour rating:

$$\Delta \geq 7{\cdot}646 \times 10^{-4} \times (b_e + b_i)\,(1 - k)$$
$$(1 - k) \leq 1308\,\Delta/(b_e + b_i)$$
$$(\Delta t - k\Delta t) \leq 1308\,\Delta t\Delta/(b_e + b_i)$$

If we now check the value of Δ used in our first numerical example by means of eq. (VII), we find:

$$(\Delta t - k\Delta t \leq 2616 \times 4{\cdot}5 \times 10^{-3}/(1{\cdot}1625 + 1{\cdot}021),$$
$$\text{or } (\Delta t - k\Delta t) \leq 5{\cdot}391° \text{ C.}$$

Thus, in order to have $p_e < p_i$, the radial temperature difference within the bar should not exceed 5·391° C. In practice, this limitation is more than ample, since, generally, the temperature drop within the bar is only 10–20 per cent of the total temperature drop between the running surface and the free surface of the commutator hub, and the greatest part of the temperature drop occurs in the mica cone caps, which are poor heat conductors.

From eq. (VI) a general conclusion of a practical nature can be derived. In order to obtain a reasonably low value for Δ, while ensuring that both the flank pressures due to assembling and the dimensions of the tightening bolts will remain small, it is advisable to maintain the radial temperature drop in the bar as low as possible. This is possible either by protecting the free commutator sleeve surface against intensive cooling or by returning the hot air stream (from the commutator surface) under the sleeve before it leaves the motor; this method is frequently applied to traction motors, and reduces somewhat the stresses produced by longitudinal (axial) thermal expansion of the bars.

For practical purposes, the transverse expansion is qualitatively* determined by eqs. (V), (VI) and (VII).

LONGITUDINAL (AXIAL) THERMAL EXPANSION OF THE BARS

The problem of longitudinal bar expansion has received considerable attention and has given rise to a large variety of designs, the main features of which are a subdivision of the bar length, the insertion of springs or spring washers under the nuts of the tightening bolts, and the use of relatively long tightening bolts. The last-mentioned feature has the advantage of being simple and can give very satisfactory results, provided that the mechanical conditions are correctly assessed and that the bolts have the required elasticity. In the following lines, a fairly simple method will be set out for the solution of this somewhat tedious problem.

The bars expanding axially and the long tightening bolts form systems which are comparable to "bows and their strings." The bars are loaded by bending stresses and the bolts are subjected to tensile stresses. For a system of given dimensions, each value of axial bar expansion thus corresponds to a certain deflection. How-

*The quantitative determination of actual flank pressure increases caused by the local temperature rise is not repreduced here for lack of space, and the interested reader is referred to the original paper.—Editor.

ever, the problem is rendered more complicated by the elastic deformation of the micanite cone caps and the Vee rings. It will be assumed that the elasticity of the Vee rings is negligibly small. This is justified if the Vee rings are strongly designed, using a sufficiently sturdy material. This requirement is formulated not only to simplify the calculation and to avoid the complex problem of Vee ring stresses, but also because it is necessary that the dovetail angle of the compression rings should remain unchanged at all temperatures in the working range in order to maintain the commutator as compact as possible, It will, therefore, be an advantage to avoid elastic deformations of the Vee rings with all the means at our disposal.

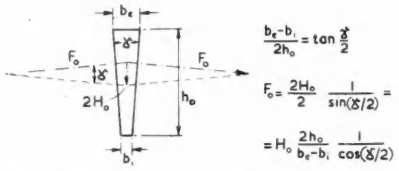

Fig. 6. **Flank forces and radial forces.**

The relationship between the flank pressure distribution and the forces acting on the tightening bolts will now be considered in this connection. As the pressures p_i and p_e are already determined by means of equation (IIa), the mean flank pressure can be calculated, and the corresponding resultant force F_o (see Fig. 6) is given by

$$F_o = (p_i + p_e)\, h_o\, l \cos(\gamma/2)/2$$

where l = a length which takes account of the notches of the dovetails, so that the product $h_o l$ represents the area of the flank of the bar. To maintain the transverse forces F_o, radial forces $2H_o$ act through the Vee rings (the factor 2 is used to denote that these forces occur in pairs acting in the same direction, and correspond to the two Vee rings). Then, from Fig. 6, we have

$$2F_o = 2H_o/\sin(\gamma/2)$$

and
$$F_o = 2h_o H_o/[(b_e - b_i)\cos(\gamma/2)]$$
$$= (p_i + p_e)\, h_o\, l/[2\cos(\gamma/2)]$$

so that
$$H_o = l(p_i + p_e)(b_e - b_i)/4.$$

The component N_o of H_o in the direction perpendicular to the side surfaces of the cone caps is determined by

$$N_o = H_o \cos\beta = p_c\,(m_1 + m_2)\, q/2$$

where β = dovetail angle, m_1, m_2 and q = dimensions of the end surface of the dovetail which is in contact with the cone cap, and p_c = pressure acting on the cap.

Substituting the value already obtained for H_o gives

$$p_c = (p_i + p_e)(b_e - b_i)\, l/[2q\,(m_1 + m_2)\cos\beta] \quad \text{(VIII)}$$

and this determines the specific pressure on the cone caps which is required in order to maintain the mean flank pressure $(p_i + p_e)/2$ under stationary conditions.

When the commutator is rotating, the pressure on the cone caps is increased by the additional pressure p_r due to the centrifugal force of the bar masses, the resultant pressure on the caps then being

$$p_c' = p_c + p_r$$

The centrifugal force per bar (the separators are not taken into account) is: $Gv^2/(gr) = Gv^2/(9{\cdot}81 \times r)$, where G = weight of one bar [kg], r = distance of its centroid from the shaft centre [m], and v = velocity of its centroid [m/sec]. If the velocity is expressed in terms of the motor speed n [rpm] and the distance r is in cm, the centrifugal force per bar is then equal to

$$F_{c.f.} = Cn^2Gr \quad \text{where } C = 1{\cdot}11786 \times 10^{-5},$$

and
$$p_r = Cn^2Gr/q\,(m_1 + m_2)\cos\beta$$

so that

$$p_c' = \frac{l(p_e + p_i)(b_e - b_i)/2 + Cn^2Gr}{[q\,(m_1 + m_2)\cos\beta]} \quad .. \quad \text{(IX)}$$

In order to determine the forces on the tightening bolts, we see from Fig. 7 that

$$M = N_o \sin\beta = [p_c\, q\,(m_1 + m_2)\sin\beta]/2$$

The increase in pressure due to rotation is not transmitted to the tightening bolts, because the oblique component of the centrifugal force (in the direction of the generating lines of the cone) is compensated by the frictional resistance between the cone cap and the dovetail if tan β is smaller than either of the two coefficients of friction mica/copper and mica/steel. Although definite numerical values for these coefficients cannot be given, it is safe to assume that the frictional resistance is sufficient, since otherwise the micanite caps would be continuously shifting backwards and forwards and thus be damaged after a short period of operation. Thus, p_c can be left unchanged in calculating the forces on the tightening bolts, which are given by

$$\Sigma M = 2K \sin\beta \times p_c\,(m_1 + m_2)\, q/2$$

where K = number of bars. Using eq. (VIII) for p_c, we obtain

$$\Sigma M = lK \tan\beta\,(b_e - b_i)(p_i + p_e)/2 \quad .. \quad \text{(X)}$$

This equation gives the sum of the tightening bolt forces for both the stationary and the rotating commutator if all the parts are at the same ambient temperature. Operation under load conditions, however, is characterised by the temperature and pressure distributions previously calculated, and the bolt forces vary under the effect of the axial expansion of the bars. Although the transverse expansion increases the flank pressures considerably, this increase does not affect the bolt stresses, since Vee rings with standard dovetail angles do not transmit these additional forces to the bolts owing to the friction between the cone caps and the adjacent metal parts. Therefore, the factor $p_i + p_e$ in eq. (X) cannot be replaced by $p_i' + p_e'$ in calculating the bolt forces under conditions of thermal expansion.

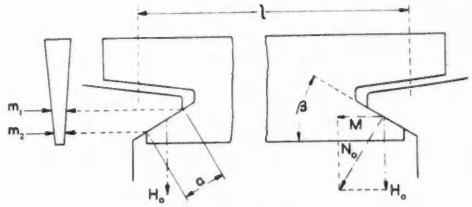

Fig. 7. **Radial and axial forces.**

The longitudinal expansion of the bars is given by $l' \propto \Delta t'$, where l' is the distance between the centroids of the trapezoidal dovetail front surface with the dimensions m_1, m_2 and q (see Fig. 7), and $\Delta t'$ is the temperature increase in the radial region determined by the line connecting the centroids of the trapezoidal surfaces. In most cases, this line is not over 30 per cent of the bar height measured from the narrow inner side. For constructional reasons, this height is not varied greatly and the variation is of little importance, so that in practice, $\Delta t'$ can be related to Δt and k by means of the simple expression

$$\Delta t' \simeq (0{\cdot}3 + 0{\cdot}7\,k)\,\Delta t \quad .. \quad .. \quad \text{(XI)}$$

(To be concluded)

Recent Developments in the Non-Destructive Testing of Materials by Electrical and Magnetic Methods

By W. JELLINGHAUS. (From *Stahl und Eisen*, Vol. 70, No. 13, June 22, 1950, pp. 552-560, 28 illustrations.)

Principles, improvements, advantages and disadvantages and applications of electrical and magnetic methods of non-destructive testing are discussed, consideration also being given to oil-bath, fluorescence and thermal methods.

ALL non-destructive electrical and magnetic methods are based on the measurement of some quantity which is empirically related to the mechanical quantity under investigation. The relationship must, in general, be separately established for each material, and it should be unique. An example of a relation which is not unique is furnished by investigations by H. Springer. He developed a test for high-speed steels based on permeability measurements. Fig. 1 shows the relation observed between hardening temperature, Vickers

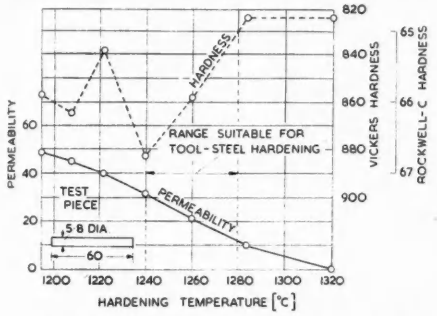

Fig. 1. **Permeability and hardness of high-speed steel as a function of hardening temperature.**

hardness and permeability. In the temperature region suitable for hardening, the relation between temperature and both hardness and permeability is linear. However, in the wider range from 1200 to 1280 C the relation is no longer unique and, thus, in this range, permeability cannot be used for hardness measurements.

Electrical and mechanical methods may be expected to yield results in the following fields of investigation:

(a) determination of mechanical characteristics of materials (under the assumption of homogeneity);
(b) measurement of the geometrical configuration (length thickness, width, cross-section, volume) of inaccessible objects;
(c) mensuration of surface layers, the magnetic properties of which differ from those of the base material (e.g., surface coating, enamelling, electroplating, case-hardening, etc.);
(d) detection of local inhomogeneities (cracks, blowholes, cavities) or of variations in electrical and mechanical properties (inclusions, stratification, non-uniform hardness, magnetic poles).

The various methods with their improvements will be dealt with under these headings, though the nature of the subjects makes some overlapping inevitable.

The simplest method of distinguishing materials by means of their different permeability (e.g., for sorting purposes) is the use of a permanent magnet. An improved form capable of distinguishing between permeabilities of 1·1 and 1·5 gauss/oersted consists of a yoke built up from mild steel plates and energised by an alternating current. The magnet forms one arm of a bridge circuit, and is balanced against a similar yoke, the magnetic circuit of which is closed through mild steel with an adjustable air-gap (Fig. 2). This simple instrument is suitable for covering large surfaces in a short time.

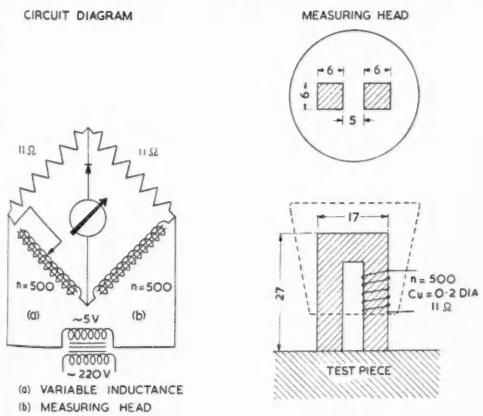

Fig. 2. **Measurement of permeability in weakly ferromagnetic substances.**

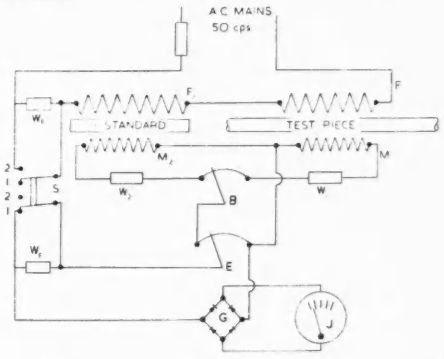

Fig. 3. **Measurement of permeability in rods and tubes by a difference method.**

For strongly ferromagnetic materials, the relative difference in permeability of which is less than 10 per cent, K. Matthaes[1] uses a potentiometer method, in which the voltages across two solenoids, enclosing the pieces to be compared, are in opposition, and a differential reading taken (Fig. 3). A suitable value of the energising field must be established in advance. For normal constructional steels, permeabilities vary over a wide range; thus, for workshop purposes, a low or medium field will give sufficient sensitivity. An interchange of the test pieces is useful for increasing the sensitivity.

Investigations carried out by the author show that the magnetic quantity best correlated with tensile strength is remanence, see Fig. 4. Since the usual d.c. methods of remanence measurement are unsuitable for workshop purposes, it is suggested that measurement be made of the instantaneous induced voltage corresponding to the zero value of the a.c. magnetising

current, using a half-wave rectifier and phase shifter. The use of the half-wave rectifier also allows of determining the sign of any deviation from the nominal value.

W. Gerlach[2] employs an eddy current method for non-magnetic materials. A rotary magnetic field of low or medium frequency is used to induce eddy currents in the test piece. The induced currents tend to diminish the generating field, and this tendency increases with the cross-section of the conductor and with conductivity. The relation between the magnetic field at the surface of a cylindrical conductor, H, and the field H_d at a radial distance d from the surface is

$$H_d = H_0\, e^{-\beta d} \qquad .. \qquad .. \qquad (1)$$

where $\beta = \sqrt{\pi f k \mu}$; f = frequency; k = conductivity; and μ = permeability.

Thus, for a given frequency and permeability, the inductive reactance of a coil decreases with increasing conductivity of the core. The energy dissipated by the eddy current is taken from the field, thus increasing the active component of the impedance. With a large increase in the product βd, the eddy current drops again, and it can be shown that the ohmic resistance as a function of $\beta d = x$ has a maximum. Fig. 5 gives the functions

$$F_1(x) = \frac{1}{x}\,\frac{\sinh x + \sin x}{\cosh x + \cos x}$$

and

$$F_2(x) = \frac{1}{x}\,\frac{\sinh x - \sin x}{\cosh x + \cos x}$$

The inductive reactance is then given by

$$\omega L = \omega L_0\, F_1(x)$$

and the eddy current resistance by

$$R_e = \omega L_0\, F_2(x)$$

where L_0 = self-inductance of the coil.

Fig. 5 shows that for small values of x, a change in x has an opposite effect on the active and reactive components of the impedance. The analysis applies to flat plates, but the functions can be used for thin-walled tubes as a first approximation. For values of $x < 0{\cdot}5$ (i.e., for non-magnetic metals of about 1 mm thickness and frequencies below 2 kcps) an approximation may be used, while another approximate formula applies for $x < 4$. These are given in Table 1. Solid bodies, e.g., bars and rods, require a different treatment, not considered here.

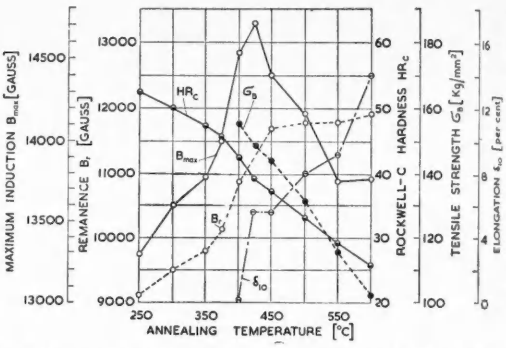

Fig. 4. **Magnetic and strength properties of strip steel as functions of the annealing temperature.**

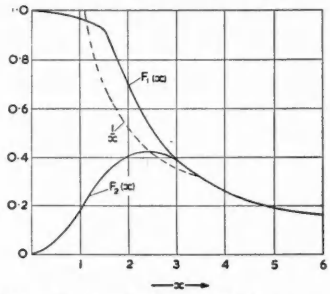

Fig. 5. **Chart for the calculation of inductance and ohmic resistance with the eddy current method.**

A bridge circuit for testing rods and tubes, due to W. Schirp[3], is shown in Fig. 6, which is self-explanatory. Fig. 7 shows the relation between tensile strength or 0·2 per cent yield strength and tempering heat on the one hand, and test instrument reading on the other. The nearly linear relations prove the suitability of the eddy current method. A modification for use on flat surfaces employs an induction coil, which can be placed in contact with the surface and the inductive resistance of which varies as a function of the conductivity of the material. Fairly high frequencies (5 to 100 kcps) are used with this contact method, and the consequently small penetration of the field renders the method

TABLE I.—FORMULAE FOR EDDY CURRENT METHOD.

	General Formulae	Approximate Formulae	
		for $x < 0{\cdot}5$	for $x < 4$
Ohmic Resistance R_w	$\frac{\omega L_0}{x}\,\frac{\sinh x - \sin x}{\cosh x + \cos x}$	$\frac{1}{12} K \mu \omega^2 d^2 L_0$	$\frac{1}{d}\sqrt{\frac{4\pi f}{K\mu}}\, L_0$
Inductance L	$\frac{L_0}{x}\,\frac{\sinh x + \sin x}{\cosh x + \cos x}$	$\sim L_0$*	$\frac{L_0}{d}\,\frac{1}{\pi f K \mu}$
Inductive Reactance ωL	$\frac{\omega L_0}{x}\,\frac{\sinh x + \sin x}{\cosh x + \cos x}$	$\sim \omega L_0$	$\frac{L_0}{d}\sqrt{\frac{4\pi f}{K\mu}}$
Current i	$\frac{E}{\sqrt{R_w^2 + \omega^2 L_2}}$	$\frac{3E}{L_0 \pi^2 f^2 K \mu d^2}$	$\frac{E}{d L_0}\sqrt{\frac{K\mu}{8\pi f}}$

* d.c. inductance.

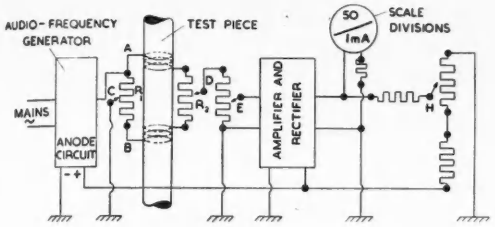

Fig. 6. **Eddy current testing of non-magnetic rods and tubes**

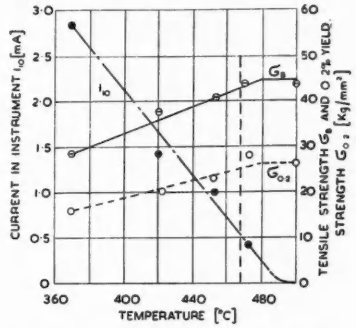

Fig. 7. **Eddy current testing of duralumin rods for heat treatment faults.**

practically independent of the cross-section of the test piece. A refinement includes a cathode-ray oscillograph which shows the voltage as a function of the phase angle, thus indicating whether deviations from a normal reading are due to inhomogeneity or to cracks or other faults in the material.[4]

As is well known, the measurement of a magnetic flux or magnetic moment always involves a geometrical magnitude. The possibility thus exists of determining cross-sections, volumes and even weights of ferromagnetic bodies by magnetic measurements, when they are inaccessible to mensuration. R. Berthold* describes an electromagnetic yoke for wall thickness measurements.

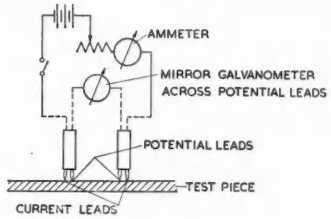

Fig. 8. **Electrical determination of wall thickness.**

When the yoke is placed against the wall, the flux through it is given by

$$\Phi = \frac{0{\cdot}4\,ni}{\dfrac{l_1}{\mu_1\,a_1} + \dfrac{l_2}{\mu_2\,a_2}} \quad .. \quad .. \quad (2)$$

*See also *The Engineers' Digest*, May, 1950, pp. 162-163.

where ni = number of ampere-turns, l_1 = length of magnetic path in yoke; l_2 = length of magnetic path in specimen; and a = cross-sectional area.

The instrument is so designed that generally $\mu_1\,a_1 \gg \mu_2\,a_2$, and as l_2 is fixed by the separation of the poles, Φ essentially depends on $\mu_2\,a_2$. The flux is measured ballistically, and the instrument is suitable for walls up to 10 mm in thickness.

An electrical method, dependent on voltage-drop measurements, can be employed for all good conductors, provided their resistivity is known. The principle of a method due to R. M. Thornton and W. M. Thornton[5] is shown in Fig. 8. Their method allows for the spreading of the electrical lines of force across the width of the specimen. High-intensity currents are employed and a sensitive galvanometer is required. The internal resistance of the apparatus must be great in comparison with that of the specimen.

For the thickness measurement of non-magnetic layers on the surface of ferromagnetic materials, AEG have developed an instrument[6] based on an inductance bridge method similar to the one discussed for permeability measurements.

Another, semi-mechanical, instrument for this purpose consists of a strong permanent magnet with spherical mild-steel pole-pieces, which are placed in contact with the surface (Fig. 9). As the attractive force exerted by the magnet is proportional to Φ^2/a and Φ (by eq. (2)) is inversely proportional to $l_2/\mu_2\,a_2$ (where l_2 in this case represents the thickness of the non-magnetic layer of permeability 1 and a_2 is an approximate value of the area of contact), it can be seen that an increased thickness of the layer reduces the attractive force. By means of an extension spring and a pointer moving over a directly calibrated scale, the thickness can be read off at the instant when contact with the surface is just broken.

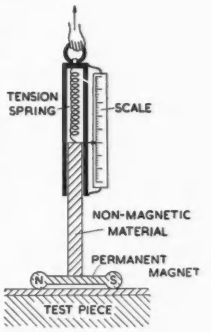

Fig. 9. **Instrument for measuring the thickness of non-magnetic layers deposited on steel.**

The measurement of a magnetically soft layer over a magnetically hard base (e.g., surface decarburisation of hard steel) should be possible by means of a mild-steel yoke, in which an alternating field of small amplitude is induced.

The determination of depth of case-hardening, i.e., the measurement of a magnetically and mechanically hard layer over a fairly soft base, presents much greater difficulties, as the permeability of the layer (of the order 50 gauss/oersted) is no longer negligible. An arrangement for this purpose is shown in Fig. 10. The mild-steel yoke is given a 50 cycle, small amplitude excitation and forms an inductance bridge with another similar yoke closed through iron. With ground surfaces, the method gave results which were reliable only within $\pm$ 0·3 mm. Reducing the cross-section of the yoke increases the sensitivity somewhat.

A procedure based on skin-effect phenomena, though giving overall values only, has been developed by O. Maercks.[7] With a suitable choice of frequency, only the surface layer will carry current. On varying the frequency, the power consumption will go through a maximum value corresponding to a penetration equal to the thickness of the layer. An accuracy of $\pm$ 0·1 mm is claimed.

So far, the magnetic properties have been assumed as being uniform throughout the whole test piece or

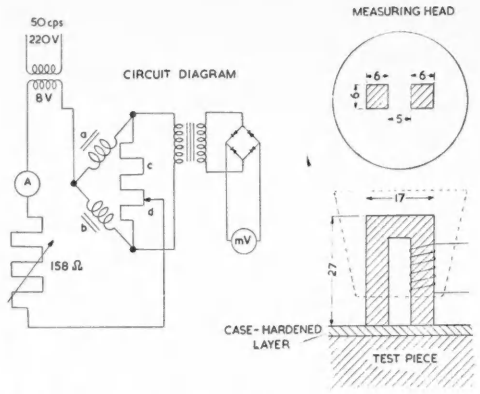

Fig. 10. **Measurement of the depth of case hardening.**

over certain layers. For the determination of local variations there are three basically different methods.

(a) Local measurement of the absolute magnitude of a physical property (suitable only for relatively large variations);
(b) comparison of local measurements at two different points by means of a differential-reading instrument;
(c) measurement of some quantity which is zero in a homogeneous material, e.g., gradient of a magnetic field, or rate of change of magnetic flux.

Measurements falling into category (a) have already been discussed. The differential measurements under (b) can best be carried out by using a fixed distance between the two measuring heads, provided the irregularities in magnetisation extend over small volumes or surfaces only.

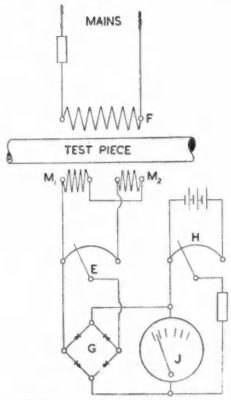

Fig. 11. **A.c. method of fault location.**

Measurements under (c) usually employ inductance methods. In the older d.c. method as well as in the newer a.c. method described by K. Matthaes[8], two opposed induction coils, a small distance apart, are used to measure the difference in flux produced by a single field (Fig. 11). Variations of 2 per cent in the cross-section are detectable, and with longitudinal magnetisation the sensitivity is more than twice as great for transverse as for longitudinal measurements. Skin-effect reduces the sensitivity for faults below the surface. According to Matthaes, the field penetration for normal constructional steels is 3 mm. His instrument incorporates automatic feed, sorting and fault location.

Rail-testing apparatus developed by Sperry[9] and Suzuki[10] also fall into category (c). Sperry uses transverse magnetisation, using d.c. of about 2500 A through the rail, and measures the field component parallel to the rail, which is normally zero. Suzuki uses a small electromagnet and measures the transverse field components. Both methods are independent of variations of the field strength, and are probably of the same practical importance.

Instead of the ballistic fault indication employed in the above methods, a constant reading may be obtained by giving the search coil a periodic motion in the field. The induced alternating voltage, for a constant amplitude and frequency of the coil movement, is proportional to dH/dx and is zero for the fault-free material. This method, due to W. Schirp[11], is illustrated in Fig. 12. At a testing speed of 0·5 m/sec, variations in cable cross-section of 0·3 per cent are still detectable. In this method a large field is more suitable for the detection of cracks and cavities, while smaller fields are used to discover inhomogeneities in the material.

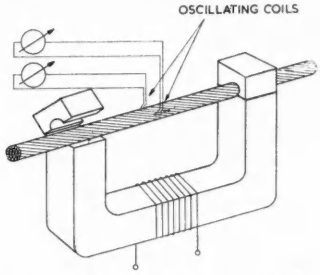

Fig. 12. **Cable testing by the oscillating coil method.**

The most important and widely applicable of all methods in this group is that employing magnetic filings. Symmetrical ferromagnetic bodies, when magnetised, will produce a uniform magnetic field near their surface, but any crack, cavity or rapid change in cross-section will cause a local inhomogeneity in the field, thus attracting filings at that point. A procedure whereby a permanent record can be made of the distribution of the filings by transferring and fixing them on to paper is described by H. Schropp[12].

Occasionally it may be necessary to locate magnetic poles which may have been produced in a ferromagnetic object (e.g., due to handling by lifting magnets), and which have a disturbing effect on their surroundings. According to investigations by the author, a way of measuring pole strength is through the variation of the differential permeability with the external field. Fig. 13 shows that the differential permeability of mild steel

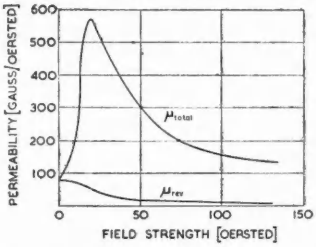

Fig. 13. **Total μ_{tot} and reversible μ_{rev} permeability in mild steel.**

decreases steadily with increasing field; thus, the rate of change of field strength can be used as a measure of the field itself. The procedure consists in producing a small (0·2 A/cm) alternating field in a search coil with a thin, very soft iron core of small demagnetisation factor. Fig. 14 shows the dependence of the permea-

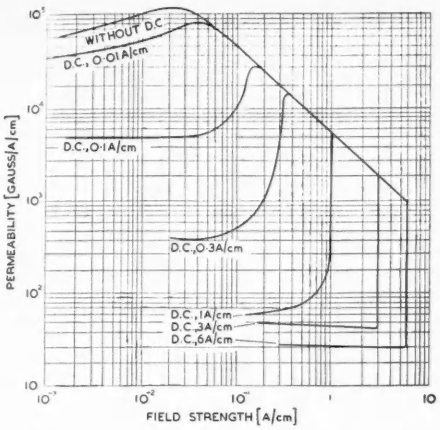

Fig. 14. **A.c. permeability of an iron-nickel alloy with different superimposed d.c. fields.**

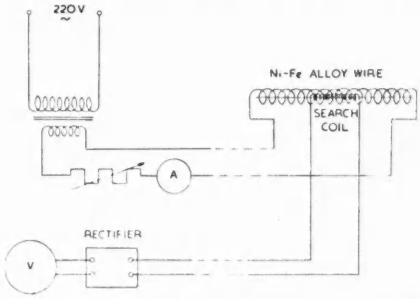

Fig. 15. **Transformer circuit for field strength measurement**

bility on the amplitude of the alternating field superimposed on various d.c. fields. It is thus only necessary to measure this permeability by a transformer method (Fig. 15) or bridge method. To locate the poles, the coil is placed with its axis parallel to the surface, and by turning it about an axis normal to the surface, the direction of minimum field strength (corresponding to maximum permeability) is found. The lines of force are orthogonal to these directions and converge at the poles. Other applications are, e.g., the measurement of coercive force, remanence or stray fields, or of the effectiveness of shielding.

The most important electrical methods of fault location are the potential drop and eddy current methods. If electrodes are placed on opposite sides of a metal plate, the current will flow around any obstacles (cracks, etc.), and the greater the area of the fault, the greater

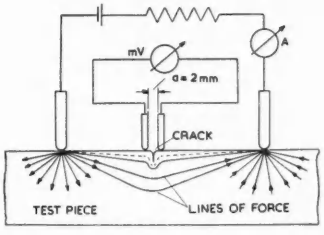

Fig. 16. **Determining of the depth of a crack by the potential drop method.**

will be the consequent potential drop. This method, however, is now displaced by ultrasonic tests. Placing the electrodes close together on one side enables the depth of any surface cracks to be measured (Fig. 16). According to Trost[13], hairline cracks of 0·1 mm depth can be detected.

Fault location by eddy current methods has already been discussed. It is specially suitable for longitudinal cracks, as with longitudinal magnetisation these diminish the eddy current to a greater extent. The sensitivity for flaws in the transverse direction has been investigated by means of transverse drillings.

Finally, some other non-destructive processes may be mentioned. The fluorescence and oil-bath methods both involve heating the test piece in a bath. On subsequent cooling, any cracks or cavities will take up some liquid. On re-heating after the surface has been cleaned, some liquid will be expelled, and faulty spots are indicated by discoloration or fluorescence. The American "Hyglo" or "Mangaglo" process employs liquids of small viscosity and surface tension with respect to the metal. It is eminently suitable for testing small hardened parts and castings.

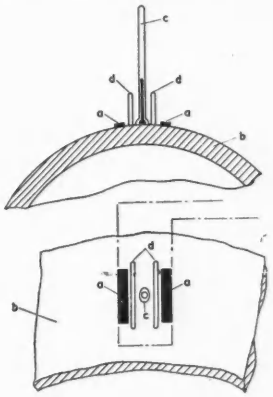

Fig. 17. **Wall thickness measurement by the thermal conductivity method.**
(a) Electric testing element. (c) Mercury thermometer.
(b) Wall to be measured. (d) Radiation shields.

Thermal processes will indicate any weakening of cross-sections through the different heat conductivity of the faulty section. The resulting temperature differences are made visible by the use of temperature-sensitive pigments.[14]. A wall thickness measurement by means of heating elements employed in conjunction with a thermocouple or thermometer (Fig. 17) is described by G. Fischer[15].

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Electric Machines of High Power-Weight Ratio

By H. LANOY. (From *Revue de l'Aluminium*, Vol. 27, No. 164, March, 1950, pp. 109-112, 3 illustrations.)

To demonstrate the astonishing progress made in recent years towards the weight reduction of rotary electrical machines and, consequently, towards improvement in the economical utilisation of material, one cannot do better than choose the most recent aircraft generators as examples. Tables I, II and III show the principal data and efficiencies of such machines, *A*, *B* and *C* being a.c. generators, and *D* a d.c. generator. From this information it will be seen that in the case of generator *C*, which is of the most recent design, the power-weight ratio even exceeds one kW per kg. It has also been claimed that in the United States an electric motor of 1000-hp capacity, 15,000 rpm, was built, which, weighing only 159 kg, represents a power-weight ratio of 4·5 kW/kg, (2 kW/lb).

Such considerable reductions in weight have been made possible by a number of developments :—

1. The use of frames, end shields, brush gear, terminal boxes, etc., of light aluminium alloys or of extra-light magnesium alloys, which, in addition to being lighter than iron, are better for heat dissipation.

2. The use of aluminium conductors for the rotor windings to reduce the centrifugal forces, which are becoming increasingly important with the present trend towards higher speeds. For instance, the conductor of the rotor of generator *B* in Table I (30 kVA, 12000 rpm), which has a circumferential velocity of 88 m/sec (289 fps), weighs only 1050 grams (2·3 lb).

3. Adoption of increasingly high speeds is made possible by improvements in ball and roller bearings as well as by the use of sealed bearings with special cooling arrangements, and forced lubricating oil circulation, and by better balancing by means of electronic balancing machines. In this connection, mention should be made of the recent introduction of silicone lubricants, which are capable of withstanding temperatures from − 35° C to + 350° C without becoming sticky, are of low volatility, and prevent seizing.

4. The adoption of temperatures up to 200° C in place of a temperature of 90 to 100° C as was hitherto considered the limit ; this change was made possible by the introduction of glass fibre and inorganic silicone insulation for the winding. Oxidised aluminium conductors can also be of considerable service, their insulation—a thin layer of aluminium oxide—having a very high melting point indeed. Forced ventilation is used and this is very carefully designed. The cooling air is brought direct into the machine under pressure through a special duct leading in from the front of the aircraft. In the case of d.c. generators, the shaft, rotor and commutator are hollow ; in the case of a.c. generators, the air can circulate through ventilating ducts. Cooling fans in light alloy are mounted on the shafts. The volume of cooling air flowing through these machines reaches 6 to 7 m³/min (212-247 cu ft/min) and the dynamic air pressure is of the order of 150-200 mm water.

5. The use of low-loss magnetic materials, which at the same time allow a higher magnetic induction ; a tooth flux density of up to 25,000 gauss can now be reached.

TABLE II.—POWER-WEIGHT RATIOS OF THE MACHINES IN TABLE I.

Machine	Normal rating W/kg	50% Overload for 5 minutes W/kg	100% Overload for 5 seconds W/kg
A	545	820	1090
B	700	1050	1400
C	922	1383	1844
D	445	670	

TABLE III.—OTHER MECHANICAL AND ELECTRICAL CHARACTERISTICS OF THE MACHINES OF TABLE I.

Machine	Rotational speed rpm	Peripheral speed m/sec	Induction gauss	A/cm	Density of energy flow through air gap, kW/m²
A	6000	53	7000	200	530
B	12000	88	4000	250	450
D	4500 to 10000	55 (average) to 60·5	10500	300	1410

6. Perfect stamping of magnetic sheet, avoiding the formation of even the slightest burr ; this reduces the "swelling" to less than 0·1 per cent, and thereby reduces the size of the machine.

Thus, for instance, a motor for use on board aircraft of rated 400 W, 24-27 V d.c., 7500 rpm, continuous operation, now weighs less than 4 kg, and an asynchronous industrial motor of the same capacity, but running at 1400 rpm, weighs 9 kg, the frame, fan and terminal box, etc., being in light alloys, which account for 4·31 kg, i.e., 48 per cent of the total weight as follows :—

Frame	3·230 kg
Terminal box	0·075 kg
Fan	0·125 kg
Coil formers	0·245 kg
Bearings (2)	0·460 kg
Terminal clamps	0·175 kg

An identical motor using iron for these parts weighs 9 kg.

The new three-phase asynchronous motors for 400 cps, for use on aircraft, are also very light due to the high speed adopted and their simple construction as squirrel-cage motors, their dimensions being correspondingly small. Thus, for instance, the volume of a 7-hp motor of this type, for intermittent operation, 200 V, 7400 rpm, was found on investigation to be only 60 cu in.

Technical Considerations and Prospects for the Future.

A peripheral velocity of 88 m/sec, for which generator *B* in Table III is designed, is not the maximum attainable ; this is limited by the strength of the material used, as velocities of 140 to 150 m/sec are in current use for power station turbo-generators. At present, velocities up to 200 m/sec can be anticipated, which would correspond to a speed of the order of 20,000 rpm for a 30-kVA generator of 20-25 cm rotor diameter for use on aircraft. The progress made in the design and manufacture of bearings and in the technique of balancing makes such speeds feasible, which, in turn, would

TABLE I.—CHARACTERISTIC DATA OF A.C. GENERATORS, *A*, *B*, *C*, AND D.C. GENERATOR *D*.

Machine	Power kVA	Voltage	Frequency cps	cosine φ	Speed rpm	Overspeed rpm	Overload 5 min—50% kVA	Overload 5 sec—100% kVA	Weight kg
A	35	120/208	400	0·7	6000	9000	53	70	45
B	30	120/208	400	0·7	12000	18000	45	60	30
C	40	120/208	400	0·75	6000	9000	60	80	32·5
D	10 kW	28·5			4500 to 10000	11000	15 kW		22·5

bring about yet a further improvement in the power-weight ratio.

The capacity per square metre of the total surface of the air gap of the generators *A*, *B*, and *C* of Table III is 530, 450, and 1410 kW respectively. In comparison with this, 8000 kW/m² has already been reached on large turbo-generators, and 10,000 kW/m² can be expected to be reached in the near future. Assuming a peripheral velocity of 200 m/sec, values of up to 56,000 kW/m² should be possible even when using materials of commercial mechanical and magnetic properties, and possible improvements in the power-weight ratio are not taken into account.

On the other hand, the magnetic flux densities at present used appear to be less amenable to improvement. Although it may be possible to design for a tooth flux density of 24,000 gauss by employing recently developed magnetic materials, a limit is set by the saturation and the resulting stray fields. It is also thought that, on the grounds of pure physics, conditions in this respect could not materially be improved even by using pure iron. However, some physicists foresee the application of intense magnetic fields without the use of iron ; Kapitza, for instance, produced a field of 300,000 gauss in small coils energised by impulse currents of very high intensity. The energy losses in these experiments—which are still in the laboratory stage—are, of course, prohibitive for any immediate practical application, but the work in this field may well lead to new conceptions which may bring about considerable improvements in the design, and weight, of the motor of tomorrow.

An important problem in the design of electrical machines is, of course, the cooling system, as about 40 per cent of the losses of large generators are due to this system alone. In principle, cooling is merely a matter of circulating a cooling agent, air, water, oil, etc., around the active parts of the machine. In America, experiments have been carried out with water cooling of a polyphase induction motor of 1000 hp, 2400 rpm, measuring only 770 mm in diameter and 990 mm in length. Work has also been carried out on the use of freon for cooling highly stressed motors ; the refrigerant is introduced in liquid form through the hollow shaft of the motor, evaporates, and escapes in gaseous form at the other end of the shaft. By evaporating, it cools the rotor and thereby indirectly also the stator ; by flowing through the shaft it cools the bearings. The flow of the refrigerant is regulated in such a manner as to maintain the temperature of the motor constant, which makes it possible to control the winding resistance and thus the slip. A 3-hp motor of this type, running at 18000 rpm, with end shields and terminal boxes of light alloy, weighs only 1·8 kg. It has a total length of only 170 mm and a diameter of 50 mm.

ITALY

Contribution to the Study of Synchronous Reactances

By S. B. Toniolo. (From *L'Elettrotecnica*, Vol. 36, No. 8 bis, September, 1949, pp. 401-405, 10 illustrations.)

This article describes a simplified method for the determination of the operating characteristics of synchronous salient-pole machines. The direct and quadrature axis reactances are measured with a stationary armature, the machine being excited with short pulses of continuous current. The circuit arrangements used for the measurements are given, and the test results obtained are in agreement with those based on direct measurements under normal operating conditions.

The behaviour of a synchronous machine can be predetermined for any stable operating condition with a balanced load when the synchronous reactances X_d and X_q (direct and quadrature reactances) are known.

Taking account only of the components of fundamental or synchronous frequency, the reactances can be determined, in principle, as functions of three parameters, for instance, the phase voltage V, the phase current I_2 and the corresponding phase angle ϕ, as shown in Fig. 1. In this same figure, E denotes the induced e.m.f., assuming that there is no variation in

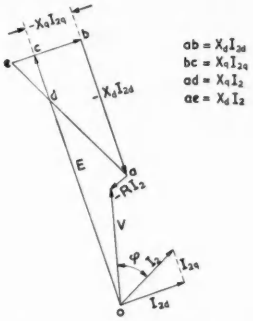


Fig. 1. **Two-reaction diagram for typical operating conditions of the salient-pole synchronous machine.**

magnetic reluctance when the flux in the iron is varying. The direction of the vector **E** is given by

$$\mathbf{V} + \mathbf{RI}_2 + j\mathbf{X}_q I_2 \quad .. \quad .. \quad (1)$$

and its magnitude is obtained by projecting along this direction the absolute value of

$$\mathbf{V} + \mathbf{RI}_2 + j\mathbf{X}_d I_2 \quad .. \quad .. \quad (2)$$

The voltage E maintains the excitation current I_1 at the required value for the load considered and eliminates the current I_2.

In the following method it will be considered that the reactances can be expressed as

$$X_d = X_d(I_1, I_{2d}, I_{2q}) \quad .. \quad .. \quad (3)$$

$$X_q = X_q(I_1, I_{2d}, I_{2q}) \quad .. \quad .. \quad (4)$$

The components I_{2d} and I_{2q} (or the corresponding m.m.f.'s A_{2d} and A_{2q}) acting on the reactances X_d and X_q (or on the reluctances S_d and S_q of the magnetic paths) are considered separately, since the secondary windings are distributed along the periphery of the armature. This also simplifies the construction of the diagram, while enabling a sufficiently accurate approximation to be obtained of the resultant flux distribution existing in the machine for any load condition.

EXPERIMENTAL DETERMINATION OF THE REACTANCES

To determine directly the families of curves corresponding to the relationships (3) and (4) would require extensive testing equipment, particularly in order to obtain the angle between the vectors V and E. The method will therefore be further simplified by assuming that the synchronous reactances can be expressed as

$$X_d = X_d(I_1, I_{2d}), \quad .. \quad .. \quad (5)$$

$$\text{and } X_q \sim \text{constant}. \quad .. \quad .. \quad (6)$$

Furthermore, it is assumed that (1) the wave-form distortion of the m.m.f. of the armature will not vary

with time when the m.m.f. distribution is displaced along the gap periphery owing to the cyclic variation of the alternating current, so that this effect may be disregarded; (2) the ratio I_{2d}/I_1 will remain substantially constant for each magnetic condition of the machine, so that the flux due to I_{2d} is determined when I_1 is known. This is equivalent to stating that although the flux distribution in the machine depends on the m.m.f. distribution, it can be regarded as being proportional to the flux of the armature winding, and that this flux is not affected by appreciable variations in the reluctance determining the value of the inductance being considered.

On the basis of these considerations, the characteristics of the synchronous machine can be determined by considering the currents acting in it at a given instant during the cycle. The rotor is kept stationary, and the phase windings are supplied with continuous currents of appropriate values. Since a constant relationship has been assumed between the m.m.f.'s of the stator and rotor along the direct axis, the stator windings can be situated so that they will only generate the m.m.f. on the transverse axis, whereas the rotor windings will produce the m.m.f. on the direct axis.

The flux of the armature under cyclic magnetisation is not strictly equivalent to that of the stationary machine with magnetisation obtained by continuous currents, owing to the parasitic currents which occur in the ferromagnetic materials under running conditions. However, the experiments carried out have shown that this does not appreciably affect the accuracy of the results, in view of the low magnetic losses of synchronous machines.

TEST METHODS AND TEST RESULTS

In order to determine the applicability of the principle, various tests have been carried out, using a critically-damped ballistic galvanometer. Alternative tests could have been made with the aid of an oscillograph to determine the variation of the measured quantities as functions of the transient time required for the current to be set up in the circuits under investigation. However, preliminary tests had shown that the ballistic galvanometer would give more rapid and more accurate results.

The measuring circuit of Fig. 2 has been used to determine the inductance

$$L'_{(\Phi)} = \Delta\Phi/\Delta i \quad .. \quad .. \quad (7)$$

for each magnetic condition of the machine. The value of L' is determined relatively to an initial value L, which is obtained subsequently from calibration tests. The test points for the curves based on eq. (7) are determined using eqs. (3) and (4), and the galvanometer readings, which are proportional to L, are plotted against the current determining the corresponding value of the m.m.f. These L-values are then integrated with respect to the current, and the results are used to construct diagrams, the ordinates of which are proportional to L_i, and hence to X_i, that is, to the voltages induced in the machine when the secondary phase windings are carrying

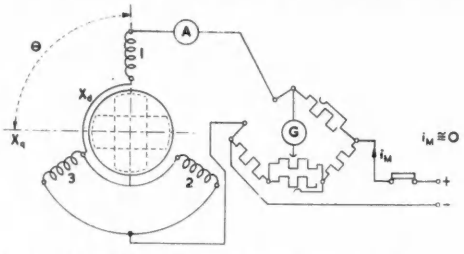


Fig. 2. **Circuit for determining the armature inductance as a function of the relative orientation θ of the field and armature, in the neighbourhood of zero flux.**

equivalent currents i which form a balanced three-phase system, and when the direction of the reaction m.m.f. vector is orientated as required relatively to the primary axis. The diagrams are then calibrated by comparing the values of the test points with those obtainable by direct tests.

The tests have been carried out on a small laboratory-type alternator with the following characteristics : phase voltage 127 ; frequency 50 cps ; maximum armature current 25 A ; non-isotropic, two-cycle alternator ; diametral pitch, with arc/pole pitch ratio of 0·74 ; mean gap 2 mm ; normal field current 5 A ; 48 semi-enclosed armature channels, with 18 conductors per channel.

By means of the circuit shown in Fig. 2, the inductance of the armature winding (corresponding to 1·5 times the phase inductance) has been determined as a function of the angle between the armature and the field windings for corresponding magnetic conditions in the neighbourhood of zero flux. The current of constant value used for the measurements with the ballistic galvanometer is the minimum required by the sensitivity of the system. The results obtained are plotted in Fig. 3. Each point is based on a number of readings taken while closing or opening the supply circuit. The amount of scatter is small and is indicated by the double lines in the figures.

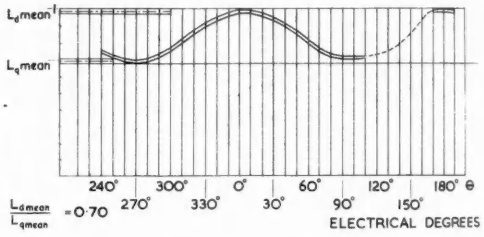


Fig. 3. **Diagram of the armature inductance as a function of the angle θ in the neighbourhood of zero flux.**

The inductance of the phase windings is determined by using the circuit of Fig. 4. The field axis is arranged so as to coincide with that of the induced phase. The circuit measures the direct inductance under magnetic conditions corresponding to given values A_d and A_q of the m.m.f.'s. In order to assess the effect of the quadrature m.m.f. on the direct-axis permeability, the measurements have been taken with the primary current increased in steps of 1 ampere at a time, and for fixed values of zero and 7·6 A for the secondary current (these being the r.m.s. values of the alternating currents which would produce similar effects in the running machine). For the machine tested, the ratio $I_2/I_1 = 0{\cdot}33$.

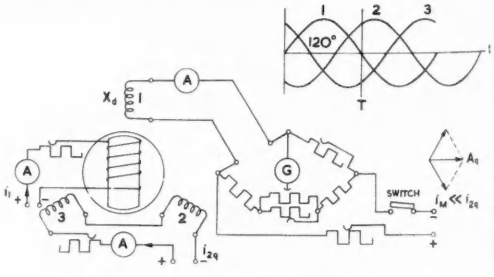


Fig. 4. **Circuit used to determine the function**
$(\Delta\Phi_d/\Delta\, i_d) = f_d\,(I_d, I_q)$ I_q = const.
$I_d \simeq$ const.

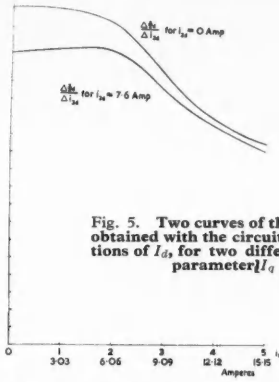


Fig. 5. **Two curves of the family of curves obtained with the circuit of Fig. 4, as functions of I_d, for two different values of the parameter I_q = const.**

The results are shown in Fig. 5. The m.m.f. on the direct axis (as determined by the currents i_{2d} and i_1) is represented on the abscissae, while the ordinates represent a quantity proportional to L_d. The vertical scale is determined subsequently from the results of the calibration tests already mentioned.

The intensity of the continuous current required to produce an effect equivalent to that of an alternating current with a balanced three-phase system under running conditions is determined, on the basis of the assumptions made, by

$$I_{2(\text{c.c.})}\ (\text{phases 2 and 3}) = 1{\cdot}21\ i_{\text{r.m.s.}}$$

for the circuit of Fig. 4.

By means of the circuit arrangement of Fig. 6, the

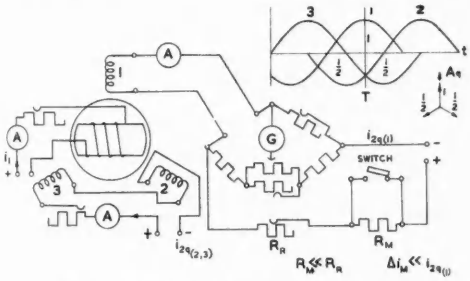


Fig. 6. **Circuit for determining the function**

$$(\Delta\Phi_q/\Delta\, i_q) = f_q\,(I_q, I_q)\quad \begin{matrix} I_d = \text{const.} \\ I_q \sim \text{const.} \end{matrix}$$

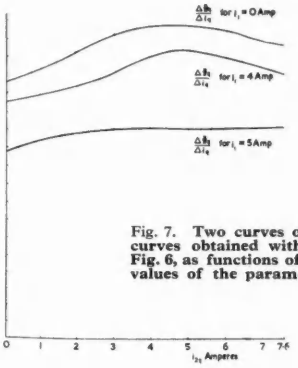


Fig. 7. **Two curves of the family of curves obtained with the circuit of Fig. 6, as functions of I_q, for different values of the parameter I_d = const.**

phase inductance has been determined when the geometrical axis of the secondary is in quadrature with the primary axis, for various values of the m.m.f.'s acting along the two axes. The results are plotted in Fig. 7.

The relationship between the intensity of the continuous current and the r.m.s. value of the equivalent alternating current is given by

$$I_{2(\text{c.c.})}\ (\text{phase 1}) = 1{\cdot}41\ i_{\text{r.m.s.}}$$

$$I_{2(\text{c.c.})}\ (\text{phases 2 and 3}) = 0{\cdot}5\ I_{1(\text{c.c.})}\ (\text{phase 1})$$

By integrating the curves of Figs. 5 and 7 with respect to the currents i_{2d} and i_{2q}, respectively, the curves shown in Fig. 8 have been obtained. The quantities represented are proportional to the voltages induced in the secondary, and are plotted against the currents generating the m.m.f.'s in the direct and quadrature axes. The scale of the ordinates has been determined experimentally for the various points by determining the voltages with the machine running normally under corresponding conditions.

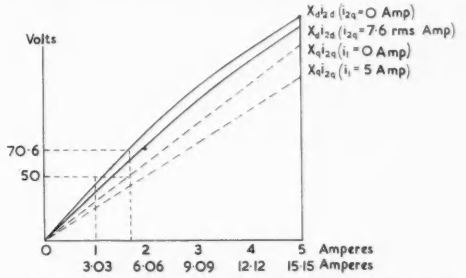


Fig. 8. **Diagram of the functions $X_d i_{2d}$ and $X_q i_{2q}$ as functions of i_{2d} and i_{2q} respectively, for different values of the parameters I_q and I_d, obtained by integrating the curves of Figs. 5 and 7, for the magnetic conditions indicated in the figure.**

The method described has been checked by evaluating the complete characteristics $X_d i_{2d}$, i_{2d} and $X_q i_{2q}$, i_{2q}, by direct methods, under running conditions, for the respective conditions $i_{2q} = 0$ and $i_{2d} = 0$. The results agree with those obtained by the simpler method.

CONCLUSIONS

The method proposed appears sufficiently simple for general application, and gives good results, with continuous currents flowing through the windings for brief periods of time.

An illustration of the accuracy of the method is given in Fig. 9. The solid-line diagram takes account of the effect on the synchronous reactances of the magnetic

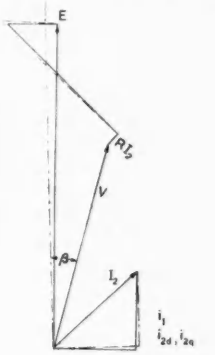


Fig. 9. **Typical two-reaction diagrams. In the chain-dotted diagram the effect of the magnetic conditions of the machine on the synchronous reactances is neglected, whereas it is included in the solid-line diagram. The diagrams also show the effect of taking account of the magnetic conditions on the angle β and the static stability of the machine.**

conditions of the machine. The chain-dotted diagram disregards this effect and is based on direct measurements, at a given load, of the terminal voltage, current and phase angle. The construction assumes that the direct and quadrature-axis reactances correspond to the values $i_{2q} = 0$ and $i_{2d} = 0$, respectively. After having determined the voltage vector **E** in this manner, and hence the angle between **E** and **V**, the values of I_{2q} and I_{2d} are obtained as a first approximation, for the load considered. This makes it possible to determine values for X_d and X_q which correspond more closely to the load condition.

The angle between **V** and **E** is reduced slightly, and to the same extent as the quadrature reactance. This is an important factor in determining the static stability limit of the machine. By determining the reactance as a function of the angle θ, as shown in Figs. 2 and 3, it is possible, however, to study the stability and the behaviour of the salient pole synchronous machine without excitation.

AUSTRIA

Tests on Streamlined Butterfly Valves

By H. NETSCH and F. SCHULZ. (From *Maschinenbau und Wärmewirtschaft*, Vol. 4, No. 9, September, 1949, pp. 141-147, 13 illustrations.)

This article gives the results of comparative tests made with throttle discs of various types. It is shown that aerofoil-type discs have lower resistance coefficients than flat or symmetrically tapered plates, and that they can be used as self-closing devices in conjunction with bent duct systems.

THE throttle discs of butterfly valves are usually characterised by two parameters, i.e., the torque coefficient k_T and the flow coefficient k_F.

If T_{st} is the torque acting on one half of the valve disc in the closed position, and T the dynamic torque about the disc axis, then k_T is defined as

$$k_T = T/T_{st} \qquad .. \quad .. \qquad (1)$$

The static torque is given by

$$T_{st} = (p_0 - p_2)\, D^3/12$$

where D = duct diameter, p_2 = pressure behind the valve, and p_0 = total pressure at inlet section of duct ahead of the disc.

The flow coefficient k_F is defined as the ratio

$$k_F = Q_{eff}/Q_{th}$$

where Q_{th} is the theoretical quantity of fluid flowing through the duct in the absence of a valve, and Q_{eff} is the quantity effectively flowing through with the butterfly valve under the same pressure difference $p_0 - p_2$.

If the flow quantities are determined from velocities and these are obtained from pressure measurements, the value of k_F is given by

$$k_F = \sqrt{(p_0 - p_1)/(p_0 - p_2)}\ , \quad 0 < k_F < 1 \quad .. \quad (2)$$

where p_0 and p_2 are defined as previously, and p_1 is the pressure in the duct portion immediately ahead of the valve disc.

The relationship between k_F and Weisbach's resistance coefficient is

$$\zeta = \frac{1}{k_F^2} - 1, \quad 0 < \zeta < \infty \quad .. \quad .. \quad (3)$$

TEST INSTALLATION

The equipment used consists of a calibrated brass conduit with an internal diameter D = 10 cm. The inlet end of the duct is provided with a curved intake

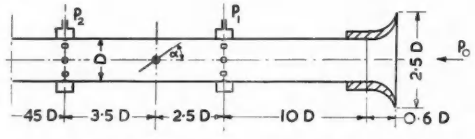


Fig. 1. **Duct used for tests, with pressure-measuring positions.**

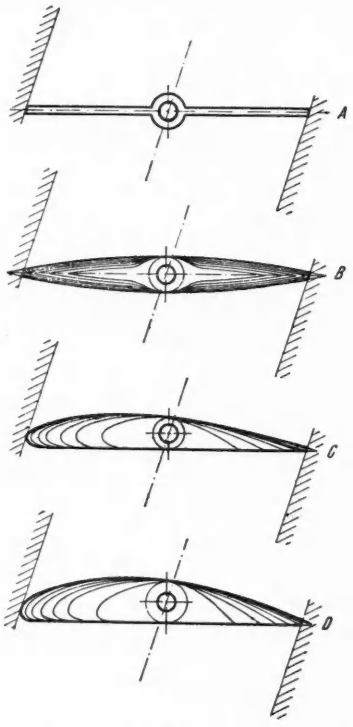


Fig. 2. **Types of throttle discs investigated.**

section, as shown in Fig. 1. The pressures p_0, p_1 and p_2 were measured in annular compensating chambers each of which is provided with eight passages. For flow measurement, standard gate-type orifices situated at a distance of 45 D from the valve disc axis were used. The rate of flow is regulated by means of a sleeve valve arranged in the duct system at the rear of the measuring duct. After passing through the sleeve valve, the working medium is aspirated by a fan, and to avoid reaction effects due to the sleeve valve, a guide vane system is

incorporated between the sleeve valve and the gate-type orifice already mentioned, at a distance of 7 D from the latter. To reduce frictional effects to a minimum, the shaft of the butterfly valve is mounted on ball bearings. As the throttle discs with aerofoil contour are not symmetrical with regard to the shaft axis, the two disc portions are balanced by means of specially cast lead inserts. The angle of incidence α of the disc relative to the duct axis is read off from a scale, the pointer being rigidly connected to the disc shaft. The dynamic torque T occurring while the fluid is flowing through the duct is measured by a weighing device connected to the disc shaft.

TYPES OF THROTTLE DISCS INVESTIGATED

The various types of throttle discs investigated are illustrated in Fig. 2, and described in the following table:—

Type	A	B	C	D
Description	Flat plate of constant thickness 0·02 D	Symmetrically tapered disc	Thin streamlined disc, Göttingen aerofoil section No. N.P. 593	Thick streamlined disc, Göttingen N.P. 592 with flat under-surface instead of camber
True max. length of disc	1·052 D	1·2 D	1·1 D	1·1 D
Maximum thickness	0·12 D at hub	0·12 D	0·12 D	0·149 D

All the throttle discs are of circular shape, and have a slight chamfer of 72 deg. at their contacting edges, this being the angle used for the closed position. The disc types C and D are developed from the corresponding Göttingen aerofoils by maintaining a constant maximum thickness at the shaft axis position and shortening the aerofoil contour gradually as shown in Fig. 2 (C and D).

TEST RESULTS

Curves showing the variations of the torque coefficients k_T and flow coefficients k_F for throttle discs of types A, B, C and D are given in Figs. 3 and 4. The coefficients are plotted as functions of the angle of incidence α for a Reynolds number Re = 350,000.

For the symmetrical discs A and B, $k = 0$ at $\alpha = 0°$, whereas k is negative at 0° for the aerofoil discs C and D, and only becomes positive at $\alpha = 6°$ and $\alpha = 3°$ respectively, when the plates are subjected to a pressure which tends to bring them to the closed position.

In the open position ($\alpha = 0°$), which is of primary importance under operating conditions, the resistance coefficient ζ of the two aerofoil discs C and D is 18 per cent lower than that of the symmetrically tapered disc B, as shown in the following table:—

	k_F	ζ
Discs A and B ..	0·906	0·22
Discs C and D ..	0·920	0·18

The above results show, therefore, that the values of k_T, k_F and ζ depend to a considerable extent on the type of throttle disc used, and can be varied within wide limits by using different aerofoil designs.

In order to determine the variation of k_T and k_F as functions of Reynolds number, comparative tests have been made with the symmetrically tapered disc, type C. Typical results are given in the following table:—

Re	k_T max	k_F max
220,000	0·8	0·87
350,000	0·98	0·915

Further tests at still higher Reynolds number are being contemplated, particularly in order to study the possibility of cavitation effects.

The influence of a bend in the duct, ahead of, and at various distances from the throttle disc axis, has also been investigated, the arrangement used being as shown in Fig. 5. These tests have been made using the thin aerofoil disc, type C. It has been found that

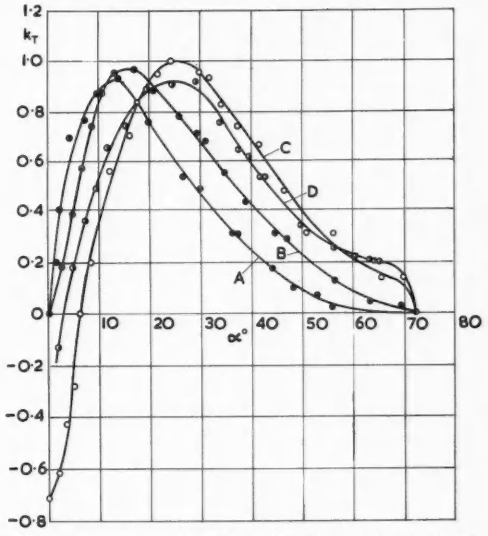


Fig. 3. **Torque coefficients k_T as functions of the angle of incidence α at a Reynolds number Re = 350,000.**

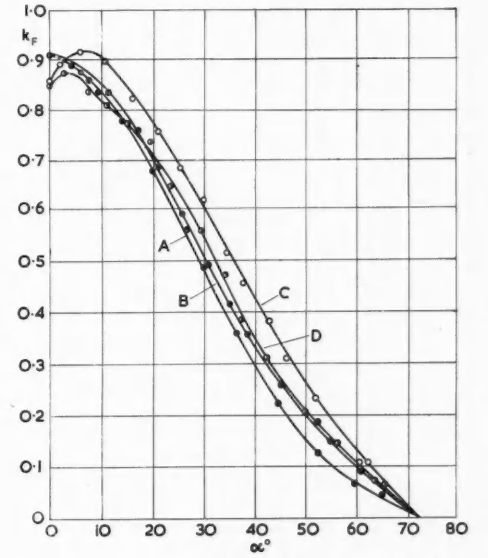


Fig. 4. **Flow coefficients k_F as functions of the angle of incidence α at a Reynolds number Re = 350,000.**

the variations of k_T and k_F follow curves similar to those previously obtained, but with somewhat lower values for k_T and higher values for k_F, as indicated in the following table:—

	Duct without bend $l_0 = 10\,D$	Duct with bend $l_1 = 10\,D$	Duct with bend $l_1 = 6\,D$
k_F max	0·92	0·935	0·925
ζ max	0·18	0·15	0·17
Variation in ζ max ..	—	17%	5·5%
k_T max	1·01	0·95	0·88

Moreover, it has been found that the value of $k_F \sim 0{\cdot}925 - 0{\cdot}935$ for the duct with a bend is practically constant from $\alpha = 0°$ to $\alpha = 7°$ for the aerofoil-type throttle disc. This makes it possible to allow a slight variation of the "open" position without appreciably increasing the resistance coefficient ζ. In particular, the disc can also be used as a self-closing valve, since any increase in flow velocity in the duct will produce an increase in the closing moment. This shows, therefore, that in a bent duct system the aerofoil-type throttle disc can be used as a self-closing valve without it being necessary to use an eccentrically pivoted arrangement to obtain the torque required for closing.

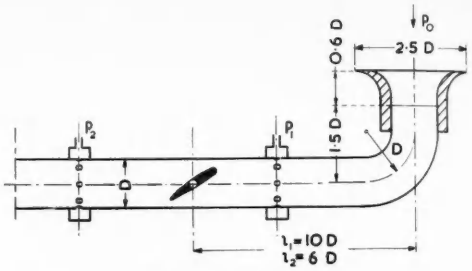


Fig. 5. **Bent duct system.**

GERMANY

A Protective Device for Centrifugal Pumps

By Fr. MARGUERRE and Fe. MARGUERRE. (Extract from an article "Means of Improving the Economy at Mannheim Power Station," published in *Brennstoff-Wärme-Kraft*, Vol. 2, No. 6, June, 1950, pp. 170-175, 7 illustrations.)

WHEN the water temperature on the suction side of a centrifugal boiler feed pump is near the boiling point, precautionary measures must be adopted to prevent overheating and steam formation in the event of the pump idling or operating at low load. The first-stage impeller and the balance disc are the parts most liable to be damaged. The usual safeguard against such damage consists in installing a by-pass valve in the discharge line which, if the output falls below a certain limit, automatically opens and allows part of the water to escape, thus maintaining a minimum flow through the pump. In most cases, these valves are operated directly by the flow of water in the discharge line, in the absence of a relay mechanism, and the authors regard the forces exerted by the flowing water as insufficient to warrant reliable cutting-in of the by-pass valve and to prevent leakage when the valve is closed under normal conditions.

In order to overcome these difficulties, a new protective system has been introduced at the Mannheim Power Station. A quantity of hot water corresponding to about 3 per cent of the normal output is taken from the discharge line and cooled in a small heat exchanger. The water, thus cooled, is fed into the restriction bush preceding the balancing device, through which it passes and is then led back to suction. In this way the critical parts of the pump are well protected from steam formation. In order to keep heat losses to a minimum, cooling is affected in two stages, as can be seen from the accompanying diagram, Fig. 1. Under normal operating conditions, 0·9 BTU per lb of water delivered is dissipated. If the pump delivers less than 30 per cent of its rated capacity, the heat to be dissipated increases to 3·6 BTU/lb, which is sufficient to operate the pump without undue risk against the closed non-return valve.

The cooler is so arranged as to allow the cooling water to flow along the entire length of the cooling coil if the full cooling effect is required, or, alternatively, only along one quarter of the cooling surface, if operating under normal conditions. The switch-over is effected by a three-way cock, actuated electrically from a pressure-operated mercury switch. In the case of partial cooling, the cooling water required may be taken from the cooling water jacket of the stuffing box.

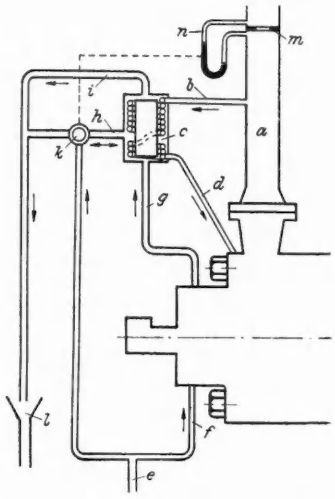


Fig. 1. **Diagrammatic arrangement of protective equipment.**

(a) Discharge line ;
(b) hot high-pressure water to heat exchanger ;
(c) heat exchanger ;
(d) cold high-pressure water to restriction bush ;
(e) cooling water main ;
(f) cooling water to stuffing box, etc.
(g) cooling water from stuffing box ;
(h) cooling water outlet when only partial cooling is required ;
(i) cooling water outlet when the full cooling effect is required.
(k) electrically operated three-way cock ;
(l) tundish ;
(m) orifice ;
(n) U-shaped mercury switch.

The authors state that the initial cost of this equipment is less than that of conventional devices. Annual saving due to the prevention of leakage losses, which have to be accepted in conventional equipment, are even more pronounced.

Gears for Extremely High Rotational Speeds

By P. BÜTTNER. (From *Technische Rundschau*, No. 11, March 17, 1950, pp. 27-29, 7 illustrations.)

A gear unit capable of transmitting 270 hp at speeds of 36,000 to 42,000 rpm is described. The design of the gears was based on a study of the causes of mechanical vibrations of gear teeth and gear noise in general, and it was thus possible to reduce gear noise to a scarcely perceptible level. The gear unit also incorporates a new system of oil cooling and lubrication which reduces the bearing temperatures at these high running speeds.

A PITCH circle velocity of about 60 to 70 m/sec (197 to 230 fps) was until recently considered as the limit for turbine reduction gears. The highest surface speeds of journals were about 50 to 60 m/sec (164 to 197 fps). However, powers and numbers of revolutions which are nowadays required are outside the range of these velocities. For instance, a gear unit with a ratio of 14 to 1 was recently required for transmitting 200 kW at a normal speed of 36,000 rpm and a maximum speed of 42,000 rpm. Some interesting features of this unit will be described here.

A. GEARS

On the assumption of a double reduction, the allowable tooth load led to dimensions which, for the specified numbers of revolutions, necessitated a peripheral velocity of 140 m/sec (459 fps), i.e., twice the value until recently considered as the upper limit. The surface speed of the journals of 110 m/sec (361 fps) was likewise considerable, so that not only the gears but also the bearings had to be carefully designed.

To achieve quiet running at high speeds, results of recent research work in the fields of acoustics and vibrations were utilised.

As gear noises are caused by vibrations, the analysis of intensity and frequency of sound serves as a guide for reducing the noise. The intensity is proportional to the square of the amplitude of vibration, and it can be kept low by suitable tooth dimensions. By choosing a suitable number of teeth, it is likewise possible to aim at a frequency of tooth contact which is favourable for quiet running.

Fig. 1 shows a simple oscillation, with the amplitude a and the period p (the reciprocal of the frequency). Vibrations of gears may be due to a number of different causes.

(1) If all teeth have a uniform pitch error, the frequency of vibration is equal to the number of tooth contacts per second. The amplitude is proportional to the pitch error.

(2) If the pinion or the gear is eccentric or unbalanced, the frequency of vibration is equal to the number of revolutions of the faulty wheel, and the amplitude is proportional to the eccentricity or the unbalance.

(3) If all teeth have a pitch error and a profile error, the vibration is composite, as shown in Fig. 2. The fundamental oscillation is caused by the pitch error, and the higher harmonics are caused by the profile error or by rough spots on the teeth.

(4) If only some of the teeth are affected by pitch errors, the oscillation has an irregular frequency.

(5) Even if the gears are faultless, there is inevitably a vibration, the frequency of which is the number of tooth contacts per second, and the amplitude of which depends on the elastic deformation of the teeth. This kind of vibration can be considerably reduced by the provision of helical or double helical gears, because inclined teeth do not go in and out of mesh simultaneously over the whole width of the gears, but do so gradually.

Errors mentioned under (1) to (4) can be almost completely eliminated by accurate and careful manufacture. The case (5) is unavoidable, even if the gears could be manufactured without any error. However, also in case (5) the intensity of sound can be reduced by keeping the tooth as small as strength considerations permit, as the tooth represents in this case an oscillating cantilever of a short free length.

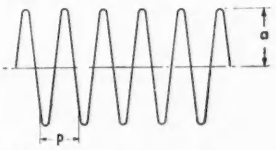


Fig. 1. **Simple oscillation.**

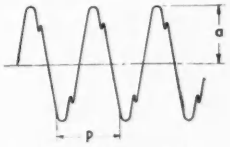


Fig. 2. **Composite oscillation.**

Fig. 3 shows the sound sensitivity of the human ear. The curves indicate the loudness in phons, as a function of both the frequency and intensity. Fig. 3 also indicates the means of keeping the loudness small.

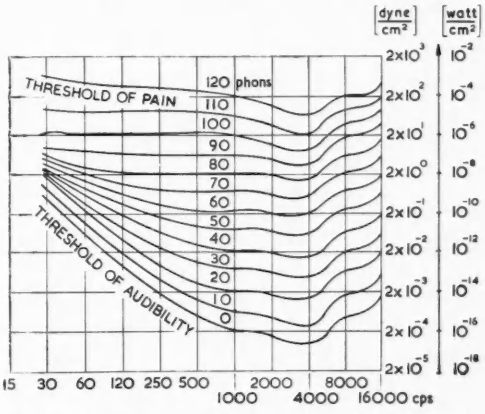


Fig. 3. **Curves of constant loudness between 0 phon (threshold of audibility) and 120 phons (threshold of pain), as a function of frequency and intensity of sound.**

To obtain quiet running of precision gears, the tooth dimensions should, therefore, be chosen as small as possible, though the frequency grows with the number of teeth. An increase in the frequency is advantageous also below 600 cps, in spite of the fact that noises of the same intensity are felt more intensely with increasing frequency; however, a smaller tooth usually has smaller pitch and profile errors, and the reduction in the intensity of vibration outweighs the influence of the increased frequency. If use is made of all available possibilities in gear design, such as correction of teeth and the advantages obtainable from helical gearing, and if materials of the highest quality are used, it is surprising what small tooth dimensions are sufficient for transmitting comparatively large forces, without overstressing the teeth.

Utilising the above considerations, the frequency of tooth contact was chosen as 16,000 cps for the first reduction; this frequency is so high that the small amplitude still existing makes the sound wave hardly audible. The amplitude could not be predicted in the design stage. Due to the favourable tooth dimensions and to careful manufacture, the amplitude was, in fact, so small that the loudness was estimated as not exceeding 20 phons, at a frequency of 16,000 cps; even when the gear noise was amplified, the noise of the first reduction gear was scarcely audible.

The numbers of teeth of the gears for the second reductions were chosen so that the frequency of tooth contact was 6,000 cps, which is still very favourable. As the module was only 2 mm, a small amplitude of vibration was also expected for this pair of gears. The second reduction gears were only slightly audible on the test bed, in the absence of amplification; however, they could be considered as noiseless from a practical point of view.

B. Housing

In designing the housing, great importance was attached to damping, and cast iron was used, as it has better damping properties than steel or steel castings. The almost perfectly silent running actually achieved can be partly attributed to the strong housing, which acts as an absorber and damps the high-frequency and low-amplitude vibrations.

C. Bearings

As already mentioned, the surface speed of the journals of the gear unit under review is 110 m/sec (361 fps). If the lay-out of the bearings had followed previous designs, the frictional losses would have considerably lowered the overall efficiency; moreover, there was little hope of keeping the bearings within a normal temperature range.

To estimate the mechanical losses to be expected in the pinion bearing, the coefficient of friction was calculated according to Gümbel's formula:

$$\mu = 0{\cdot}0055 \sqrt{\frac{\eta n}{p}\left(\frac{4d}{l}+1\right)}$$

$$= 0{\cdot}0055 \sqrt{\frac{0{\cdot}0025 \times 42000}{3{\cdot}5}\left(\frac{4 \times 5}{5}+1\right)} = 0{\cdot}067,$$

where

η = absolute viscosity of the oil [kg sec/m^2]; n = revolutions per minute; p = pressure [kg/cm^2]; d = journal diameter [cm]; and l = length of journal [cm].

The resultant comparatively high value of the coefficient of friction gives rise to doubt as to whether Gümbel's formula is still valid for very high numbers of revolutions.

The coefficient of friction could have been reduced by increasing the pressure, i.e., by reducing the bearing area. This was not attempted as, according to Lasche, the bearing pressure in the pressure area increases considerably with higher sliding velocities; the pressure amounts to 3·7 times its original value, at about 60 m/sec, and to about 5 times its original value, at about 110 m/sec, so that the actual pressure is of the order of 17·5 kg/cm^2 (249 psi).

As indicated by the above formula, another possibility of reducing the coefficient of friction could have been the use of a lubricating oil with a lower absolute viscosity. This was likewise unfeasible, as the same oil was used for the lubrication of the bearings and the gears. An oil of lower viscosity would have been detrimental for the latter purpose.

To reduce the work of the oil in the bearings, an improvement in the coefficient of friction was, therefore, sought in the field of hydrodynamics. A smaller bearing clearance than the standard was chosen, so that only that amount of oil is pumped through the pressure area which is necessary for a sufficiently thick oil film.

The journals were particularly carefully ground, and the bearing sleeves had a high surface finish, so that fluid friction was ensured, in spite of the reduced clearance.

Whilst the cooling oil for turbine bearings is usually introduced in counterflow through recesses in the unloaded area of the sleeve, in the case under review an ample supply of cooling oil is introduced into longitudinal ducts on either side of the bearings. These ducts have uniform cross-sections and extend over the whole length of the bearing, communicating at both ends of the bearing with the exterior, so that the fast-running shaft is in continuous contact with two streams of coolant (Fig. 4).

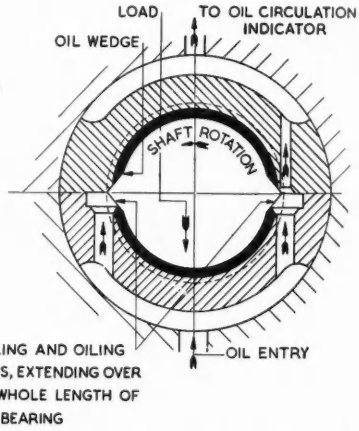


Fig. 4. **Modified oil cooling for turbine bearing.**

The correctness of the cooling arrangement can be judged from the fact that the outer pinion bearing had a higher temperature than the two inner bearings, in spite of a smaller journal diameter and a surface velocity of only 88 m/sec (289 fps). In the case of the outer bearing, the cooling oil flows practically entirely through the opening on the inside, as the duct on the outside is almost ineffective because of the nearby seal. This comparison is the more interesting as the exposed outer bearing benefits from the ventilating effect of the adjacent tooth clutch, which, in addition, causes air cooling.

The heat balance based on the results of the test run shows that the coefficient of friction and, consequently, also the mechanical losses were at least 50 per cent lower than the value calculated above.

CRACKING OF WELDED LIGHT-ALLOY STRUCTURES

(*Concluded from page* 292)

first and only become visible at 300 to 200 °C. The eutectic skeleton, above the solidus, of hyper-eutectic materials on the other hand largely prevents shrinkage cracks.* Cracks, however, may also appear suddenly below the solidus. In order to study the mechanisms involved, the author conducted tests, as described, in a jig which allowed of measuring the shrinkage tension during cooling by means of electric resistance strain gauges.

*The eutectic alloy thus appears to coincide with the most favourable composition for crack resistance, and the percentages should not be below this optimum.

PRODUCT DESIGN AND DEVELOPMENT

Present-Day Car Design Trends

AERODYNAMIC STREAMLINING VERSUS STYLING

By TIBOR HAAS, Dipl. Ing., A.M.I.Mech.E., A.F.R.Ae.S.

THE purpose of this paper is to trace some of the many and varied engineering aspects of car design and their influence on the appearance of the present-day car. It is also proposed to discuss the considerations involved, with a view to obtaining some conception of the appearance of the car of tomorrow, assuming that the engineering factors will carry their due weight in evolving rational design.

The motorist, to whom this paper is mainly addressed, does not always fully appreciate the problems involved in automotive engineering, and is prepared to leave this subject to the designer and engineer, the motorist concerning himself mainly with function, comfort and appearance.

It is not suggested that new ground is broken with this paper, in which the engineering background is hinted at, rather than fully discussed, but body design, forming the main subject, has always been a controversial topic, and an attempt is made here not only to remove some of the misconceptions and prejudices which exist, but also to isolate the problem from apparently arbitrary influences and to reduce it to engineering factors which can be appreciated by a wider public.

Appearance and engineering progress are not divorced from each other in car design, yet misconceptions as to what is essentially an engineering problem and what is the artistic interpretation of form and balance are still prevalent even among some car manufacturers.

If the British automobile industry is to maintain the export of 75 per cent of its products, closer consideration of the requirements of its overseas customers will have to be made. In analysing the needs of our overseas customers, their mentality and background must be understood. It is the opinion of the writer that many conflicting demands could be resolved if more consideration were to be given to internationally acceptable specifications.

There are two broad groups of design views expressed in this country. One could be headed "National Design" and the other "Contemporary Design." There are definite recognizable national characteristics peculiar to each country, but as far as design is concerned, they are rather the outcome of the limitations under which they live than desirable aims. I feel that any limitation on design aims that would not admit of cosmopolitan validity is restrictive, and the sooner we abandon it the less difficulty we should find in conquering export markets. The protagonists of national trends in design seem to forget that if goods are to find a world market on merit they must have a general and wide appeal. It is my submission that truly contemporary design satisfies both home and export needs. Whilst adhering to or overstressing what is termed "traditional design," we might find ourselves divided between designing for home consumption and designing for export. I do not doubt for one moment that such a policy would lead to bad home design and equally bad export design. Those who talk of tradition in car design seem to be victims of a fallacy. They are slow to appreciate improvements and changes. Their tradition rather consists in lagging 5 to 10 years behind the times, or being at least one model late in their acceptance of body appearance design.

Let us then review briefly a number of design points that we have become accustomed to seeing in our post-war cars. For those who would wish to gain a fuller conception of the detail problems involved, references are given at the end of this paper and are indicated by superior numbers in the text.

The radiator no longer stands proud of the bonnet, the mudguards merge into the body, the once exposed lights fit flush into the wings, and exposed door hinges and running boards have disappeared. This process of integration produced the "full width" or "slab side" body of today. Contrary to public opinion, this development was essentially functional.[1]

Inherent in this integration is the tendency to form a single unit of the body with the chassis frame[2, 3]. Reasons of economy, that is to say, production, favour the adoption of integral construction, while the unified form with its smooth surfaces reduces air resistance if sufficient attention is given to aerodynamic principles. This integral construction makes for easier cleaning and, if the inherent possibilities of this type of construction are fully utilised, greater crash resistance. The power unit was moved further forward in the chassis, in order to provide passengers with inter-axle seating, tending to increase rear seat width.[4]

These new trends, if properly interpreted, could be considered a revolution in car design, yet some of the indirect results have been unnecessarily exaggerated, and have thereby obscured the very real advancement. For instance, the exaggerated bulbousness, "mouth organs" and chromium adornments for fashion or sales reasons have been the subject of constant attacks. It is here that the body appearance designer or, as he is sometimes called, the "stylist," has some useful function to perform. Instead of uncritical acceptance of these exaggerations, he could apply reticence and good taste in co-operating with the engineer. Stripped of certain exaggerations and chromium plating, some American cars have not only good form but also very good body design when measured by the criteria to be discussed later on in this paper.

One of the consequences of bringing the engine position forward was an increase in the length of the propeller shaft, which is undesirable for mechanical reasons. Another consequence of the integral construction is less accessibility and difficulty of repair.

Valid though these criticisms may be, the remedy would appear to be in finding a better location for the power unit. Some of the Continental tendencies, such as front wheel drive or rear engine location, appear to be further developments that suggest themselves. These developments conform to present-day tendencies and foreseeable trends. Of these, rear engine location lends itself to body designs with low air resistance.

In his message to members of the Automobile Division of the Institution of Mechanical Engineers, in November last year, the Chairman said: "I note the general tendency to follow, if not to copy, American automobile designs, not only in body lines, but in other details, and I sometimes wonder whether the Conti-

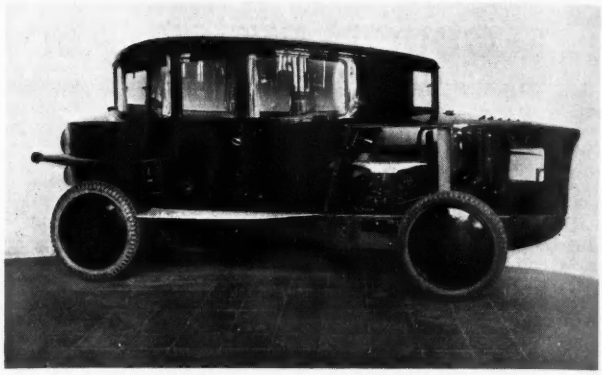


Fig. 1. **First "tear-drop" car of Edmund Rumpler, 1921. Rear-engined saloon. Wheel base 9 ft 5 in., independent suspension.**
(By courtesy of Deutsches Museum, Munich.)

nental countries, with their less orthodox developments, are not following a more realistic course."

However, even with conventional engine location, in accordance with the present trend to move the engine further forward on the chassis and to advance the rear seating with a full width body, air resistance or drag can be materially reduced despite the greater frontal area.

It is necessary to consider in some detail the factors involved in air resistance and their significance to car design.

The air resistance or drag encountered by a vehicle can be expressed by the formula

$$R = C_d \tfrac{1}{2} \rho v^2 A$$

where R = drag [lb]

C_d = coefficient of drag [dimensionless]
ρ = mass density of air [slugs per cu ft]
v = relative air velocity [fps]
A = frontal area of car [sq ft]

This is the formula used in aerodynamics, where $\frac{1}{2}\rho v^2$, known as the dynamic pressure, has some significance.

However, in England, for the purpose of automobile aerodynamics, we write the simplified formula

$$R = KAV^2$$

where K is a constant which depends on the form of the vehicle and, obviously, is no longer dimensionless

V = the relative air velocity [mph]
A = the frontal area of the car [sq ft]

The constant $K = R/(AV^2)$ serves as a measure of the aerodynamic efficiency of a vehicle (so does, of course, C_d, and it will be appreciated that, when comparing drag coefficients, care should be taken that different measuring units used be converted to the same basis). The lower the value of K, the smaller is the air resistance for a given frontal area at a given speed. For instance, for a square flat plate, $K = 0{\cdot}00325$, for a flat circular disc, $K = 0{\cdot}00284$. For a carefully streamlined car body, the optimum value ever obtainable is $K = 0{\cdot}00024$ to $0{\cdot}00030$.

Such optimum values provide an objective criterion for the designer. "Good Design" will have steadily to approach these figures without sacrificing other functional requirements and aesthetics.

At this stage, it may be worth while to note that the factors contributing to low drag values were well known to earlier car designers who were influenced in their thoughts by the developments taking place in aviation.

Fig. 1 shows one of the earliest attempts at scientific streamlining in the "teardrop" design by Edmund Rumpler, of 1921. Burney introduced his streamlined saloon car in 1930, and he showed that an ordinary saloon car on the same chassis required 100 hp to drive it at 77½ mph, whereas with the Burney type of body only 60 hp was required. At about the same time, Jaray, an engineer of the Zeppelin works, came out with his aerodynamic body design for an Opel chassis (Fig. 2) which will certainly strike the careful observer as incorporating many of the tendencies of present-day car design. For this car it was claimed that, at road speeds of about 40 mph, the fuel consumption was reduced by over 40 per cent; the lower fuel and power consumption was due solely to aerodynamic improvement of the body.

For some reason or other, these cars did not find general acceptance, and the application of aerodynamics to car design remained erratic. These early pioneers of true streamlining were to some extent ahead of their time. Nevertheless, the thoughts underlying their designs are of interest today, as we have come nearer to the possibilities of successful realisation of these ideas.

It can be seen from the formula for R that there are two ways of reducing air resistance. One is the reduction of the car's frontal area, A, that is, the maximum cross-sectional area of the car, and the other is the reduction of the constant K, the drag coefficient. The possibilities of reducing the frontal area of the car, without at the same time reducing headroom or elbow-room or causing discomfort, are limited. We are, therefore, more or less left with the alternative of reducing the drag coefficient in order to effect aerodynamic improvement.

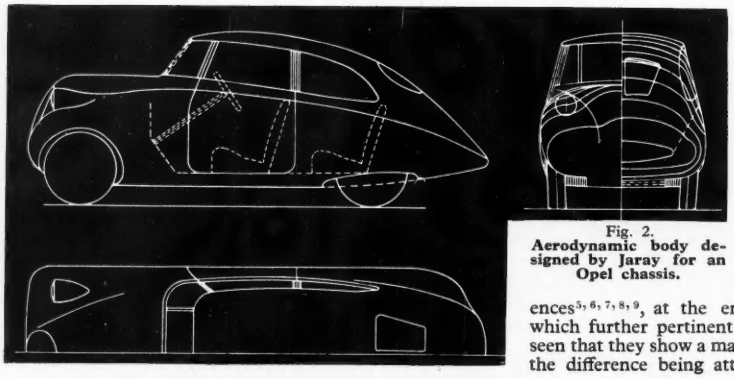


Fig. 2.
Aerodynamic body designed by Jaray for an Opel chassis.

In Table I, some of the coefficients are listed which have been obtained over a number of years. The coefficients in the table have been taken from references[5, 6, 7, 8, 9], at the end of the paper, in some of which further pertinent literature is listed. It will be seen that they show a marked difference from each other, the difference being attributable not entirely to aero-

TABLE I

Car Body Design	Test Condition	K	V_{max} mph	Ref.
1930 Sedan	Wind tunnel model	0·001547	—	5
Ideal streamline form	" " "	0·000210	—	5
1933 Conventional Sedan	Wind tunnel model 1 / 10	0·00170	76	7
(a) De Soto Airflow	Road tests	0·00140	84	7
(b) Bumpers removed, flush windows and rear wheel shields added	" "	0·00128	86·3	7
(c) New front added	" "	0·00120	88	7
(d) Front section of tail added	" "	0·00107	91·1	7
(e) Underpan and still fairing added	" "	0·00094	94·4	7
(f) Rear section of tail added	" "	0·00081	98·8	7
(g) Faired windshield added	" "	0·00079	99·4	7
Russobalt 1915	Not stated	0·00199	43·5	8
GAZ-A 1931	" "	0·00193	55·9	8
GAZ-M. 1 1936	" "	0·00126	62·1	8
GAZ-M.20 " Popieda " 1946-49. Fig. 20*	" "	0·00083	68·3	8
Healey A.S.M. 2·4 litre 1945, original model	Wind tunnel model 1/8	0·001085	—	See text
Fig. 6 Modified model	Do.	0·001045	—	" "
Original "	Do. 5° yaw	0·00119	—	" "
Modified "	Do. 5° yaw	0·00116	—	" "
Standard " Vanguard " 1947. Fig. 8	Road tests	0·00162	77	See text
Nash " Ambassador " 1949. Fig. 9	Full scale wind tunnel test correlated by road tests	0·00110	91·5	9
American car of 1949	Full scale wind tunnel test	0·00153	—	9
Tatra T.77, 1934. Fig. 12*	Wind tunnel model Road tests	0·00077 0·00102	— —	See text " "
Tatra T.87. Fig. 13*	Wind tunnel model Road tests	0·000636 0·000865	— 100	" " " "
Tatra T.97. Fig. 14*	Wind tunnel model Road tests	0·00066 0·00 89	— —	" " " "
Tatra T.600, Tatraplan, 1948. Figs. 15* and 16*	Wind tunnel model Road tests	0·00061 0·00084	— 80	" " " "
Hotchkiss-Grégoire, 2-litre, type R	Wind tunnel model 1/10 Corrected value extrapolated	0·00052 0·00082	—	15

* These illustrations will be published in the second instalment of this article—Editor.

dynamic improvement but partly to the different methods of measurement by which these coefficients have been obtained. We do not propose to discuss these methods at any length, but it is important to bear in mind where the main differences in measurement lie.

Generally, aerodynamic tests are carried out in wind tunnels on models of one eighth or so full size. The model is stationary, while the relative wind speed is produced by a fan in the tunnel's circuit. The model is mounted on scales which measure drag and other aerodynamic forces. In this way, the forces acting on the car are the same as if the car were travelling at a given speed against zero wind.

Another possibility of testing drag is the full-scale testing of cars in large tunnels, which is likely to produce the best results, but such tunnels are expensive to build and operate. If full-scale tests are made in a relatively small tunnel the drag results obtained are liable to falsification. The differences in actual drag encountered on the road and in the tunnel are due to the following causes:—

(1) Wheels in tunnel do not rotate.

(2) " Road " in the tunnel is stationary (while, in reality, it has a movement relative to the car, and no relative movement against the wind).

(3) The support of the model on scales produces drag.

(4) Tunnel wall effect, known as " blocking effect " in full-scale tests.

(5) Scale effect. (Approximately 15 per cent of the total drag is due to skin friction, and, in reproducing the surface smoothness of the actual car, the scale factor of the model must be considered. This means a very high and uniform finish for the model. The model itself, therefore, must be a very faithful scaled-down version of the actual car.)

(6) In some estimates of R, A figures as the actual frontal area of the car, while in others the entire area under the car between the wheels is included.

Therefore, without further knowledge of the measuring background, drag values cannot be taken as absolute for the purpose of comparison, but have to be taken as relative figures of merit. The standardisation of testing methods would clear the inherent doubts and enable the industry to make consistent progress in the aerodynamic design of cars. There are various means for correcting the difference in drag from tunnel tests, and these are enumerated as follows, in the sequence in which the points were made above.

(1 and 2) Account can be taken of the effect of road surface on drag by the theory of images or " aerodynamic reflection." Two identical models are used, held together wheel to wheel, and the drag value obtained is halved. When using a single model,

an endless belt can be used to imitate the relative movement of the road and to rotate the wheels.

(3 and 4) A correction factor can be applied, derived from a comparison with full-scale road tests.

(5 and 6) Consistency and accuracy to given limits are to be maintained.

What, now, does air resistance mean in terms of power consumption ? The total power of the motor, at a given speed, is made up of:

(a) Air drag.
(b) Rolling resistance.
(c) Drive system friction.
(d) Engine accessories (cooler and engine-driven accessories).

Let us now consider the proportion in which power is used up. In Fig. 3, curves of air resistance and rolling resistance for three widely different cars as to size and date of origin are plotted in terms of horse-power consumed against miles per hour. The methods of testing, whereby these curves have been obtained, are also widely different, so that the curves are not strictly comparable. This, however, does not alter the arguments and the conclusions derived from them. They rather illustrate the need for uniform testing procedures. The three cars considered in Fig. 3 are:

(1) The Healey 2·4 litre car, the body of which has been designed by Allen-Bowden Ltd., Leamington Spa. The wind tunnel tests on the model of this car were made in November 1945.

(2) The Standard Vanguard, drag values of which have not been measured in the wind tunnel but have been deduced from deceleration tests on the road. The curve described in Fig. 3 as " Standard Total " results from road tests made with a built-in dynamometer.

(3) The Nash Ambassador of 1949 (Airflyte range). On this car, full-scale wind tunnel tests have been made[9].

case to a fully laden car. This is of special importance for small cars, where the ratio of empty weight to full weight varies considerably. It appears that, for the Vanguard, the rolling resistance was measured at a slow speed and assumed to remain constant over the whole speed range.[11]

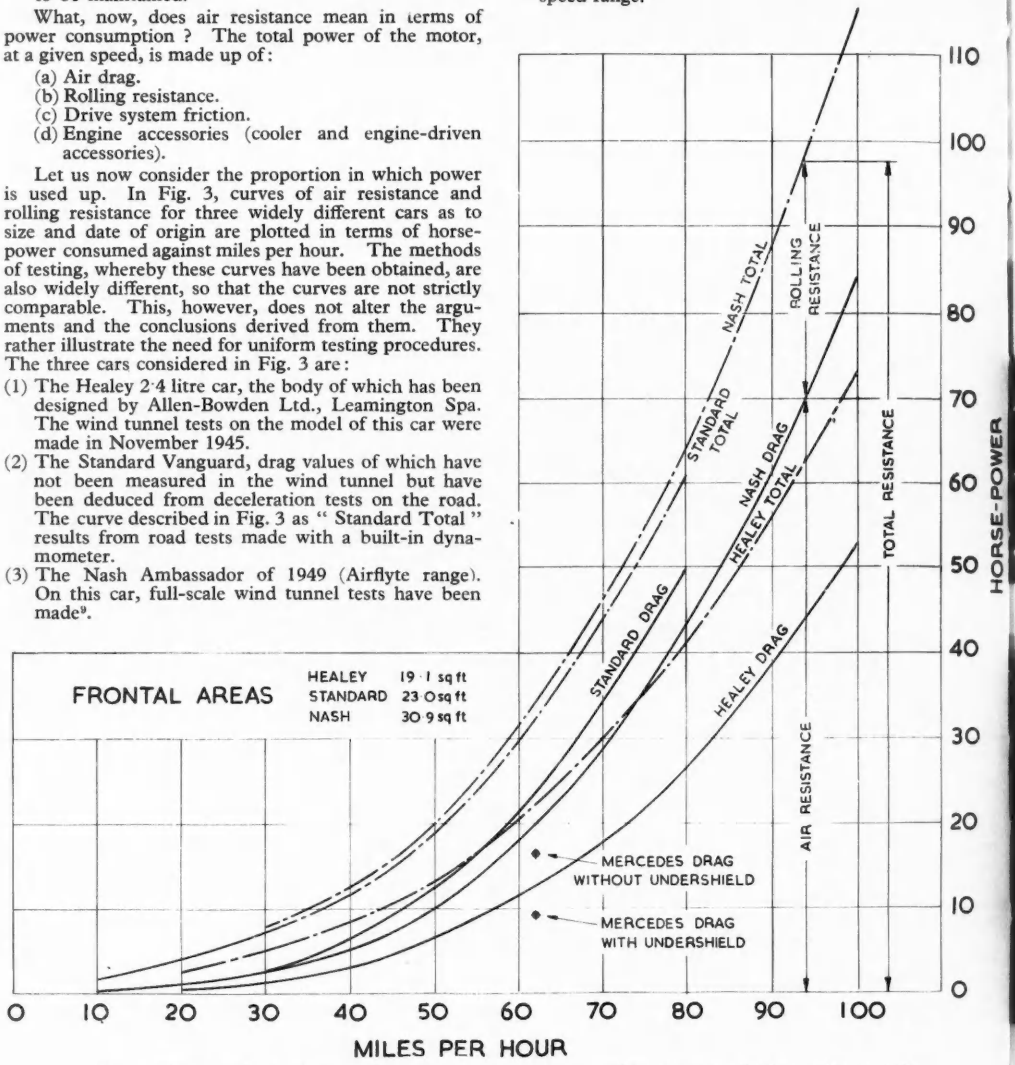


Fig. 3. **Diagram illustrating aerodynamic cleanness as expressed by power required at various speeds.**

In estimating rolling resistance, no true comparison is possible either, unless the type of tyre and the smoothness of the road surface are uniform in all cases. Coefficients of road friction differ widely[10] and, therefore, in the case of the Healey and Nash curves, the coefficient of rolling friction $\mu = 0{\cdot}0165$ has been assumed below 30 mph, above which speed the rolling resistance was assumed to increase by 1 per cent per mph. To put it differently, $\mu = 0{\cdot}0165$ represents a rolling resistance of 16·5 lb per 1000 lb car weight.

To make fair comparisons, it is therefore necessary to know whether or not the car weight refers in each

Reverting now to Fig. 3, the drag on the Healey car was determined by measurements on a $\frac{1}{8}$ scale model rigged in a wind tunnel. This is shown in Fig. 4. The car shown was later modified and tests were made on the modified model. The finally produced car is shown in Fig. 5. The effect of the road was reproduced by having the model just clear of a large horizontal flat board, as can be seen in Fig. 4. Tests were made with the model accurately down wind (zero yaw) and also at an angle of 5° to the wind (5° yaw). The drag coefficients for both conditions of the original and the modified models are given in Table I ; the drag curve

in Fig. 3 refers to the modified model at zero yaw.

Visual air flow tests have been made with the aid of streamers and smoke trails. On the original model the valley between the rear mudguard and the body was a source of turbulent flow which merged into and enlarged the wake. It is the wake behind the car that is responsible for about 85 per cent of the drag. When the valley was filled with plasticine to give a smooth sweep right over the rear body and mudguard, the flow was considerably improved and lower drag coefficients, as shown in Table I, were obtained. It will be seen from the table that an angle of yaw of 5 , corresponding roughly to a side wind of 9 mph, at a speed of 100 mph, increases the air resistance by about 10 per cent. Modification to the rear reduced the air resistance by 3 to 4 per cent.

Model smoke tests and streamer tests on a Bristol 2-litre, type 401, on the road have been conducted and

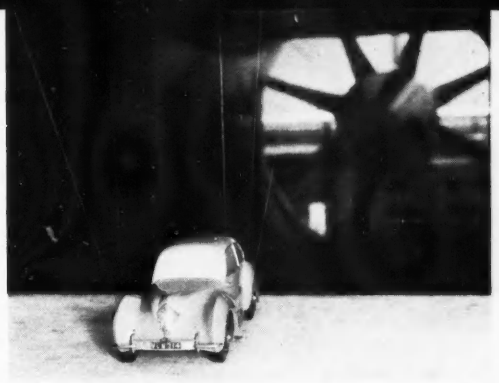


Fig. 4. **2·4 litre Healey car suspended from the test balances in the wind tunnel, seen against the background of the wind-producing fan.**

Fig. 6. **Streamer tests on a Bristol 2-litre, type 401.**

Fig. 5. **2·4 litre Healey saloon, final form of body design by Messrs. Allen-Bowden Ltd.**

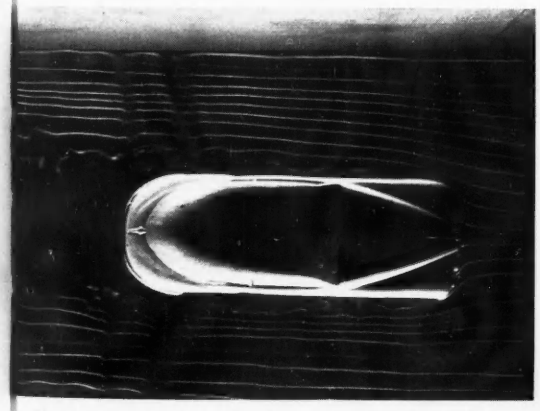


Fig. 7. **Smoke tests on a 1/16 full-size model of the Bristol car shown in Fig. 6.**

are illustrated in Figs. 6 and 7 respectively. They show that, with the exception of small local disturbances, the air flow over this very modern British car is smooth, which will no doubt be corroborated by a low drag coefficient when results become available for publication. Figs. 6 and 7 are merely shown here as useful examples for visualizing air flow, and we can revert to the discussion of Fig. 3.

The Standard Vanguard, to which the curves in Fig. 3 relate, is shown in Fig. 8. As mentioned before, the tota! power required has been obtained by dynamometer tests on the road, while the horse-power required to overcome air resistance has been obtained from deceleration tests on the road. The drag coefficient has been calculated back from results so obtained. This method of testing, dispensing with the wind tunnel, does not enable the car designer to trace local spots of turbulence, and does not provide a safe method from which aerodynamic improvements could result.

As we have already mentioned the assumptions made for calculating rolling resistance in the case of the Nash car, a brief note will suffice for describing the experimental basis on which the Nash drag curve is based. In the literature referred to[9], a description of the full-scale tests which have been made on the Nash Ambassador (Airflyte range) is available, from which

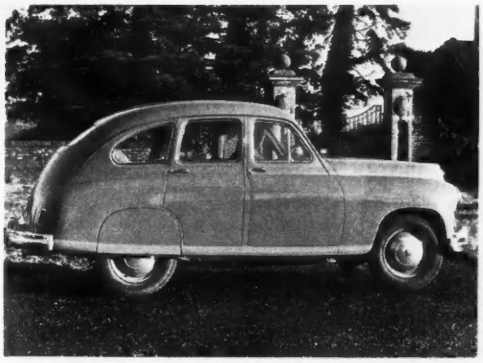
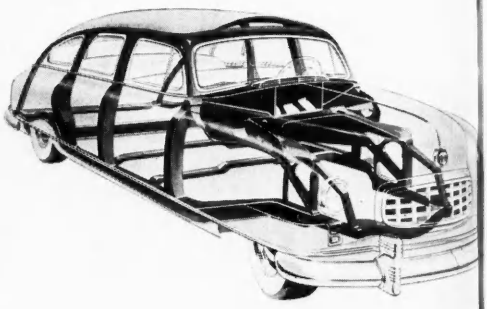


Fig. 8. **The Standard " Vanguard " saloon.**

Fig. 9 (left). **The 1949 Nash Ambassador.**

Fig. 10 (below). **Diagram showing the unitised body frame of the 1949 Nash Ambassador.**



the full significance of aerodynamic streamlining is evident.

Apart from full-scale tests in the tunnel, pressure distribution around the car was recorded on the road, and dynamometer tests have been made. These, when properly evaluated, enabled a tunnel correction factor to be obtained, which is valid for all further testing. The drag curve for the Nash Ambassador in Fig. 3 shows the already corrected values.

In earlier wind tunnel tests around the thirties, when head-lamps were exposed, it was of interest to find their influence on air resistance, and it has been found that their complete removal reduced the value of K by just over 10 per cent. Similarly, replacing the then standard underwings by the enveloping type reduced drag by over 7 per cent. To-day, these refinements have become standard practice and further refinements can only be made by thorough aerodynamic studies. In the Nash Ambassador, at 60 mph, it can be calculated that about 2·64 hp saved in air drag is equivalent to 1 mile per Imperial gallon in fuel economy. In the development of the Nash 1949 model, tests showed that by shifting the same engine from the 1948 model to the 1949 model, the aerodynamic improvement of the new body resulted in an increase in maximum speed of about 7 mph. Calculations indicated that a 7 mph greater top speed was equivalent to 20 hp. Such a saving in horse-power, due solely to aerodynamic improvement of the body shape, does therefore mean a great saving of fuel at high speeds, but even at lower speeds the saving is considerable if considered on a national scale.

Cars of other makes tested in the same way as the Nash Ambassador showed clearly that many problems of aerodynamic improvement were either not given due attention, or were overruled by the stylist. For the Nash 1950 car, 20·7 per cent less air drag is claimed than the average of all other leading American makes of cars tested. Other cars used as much as 51 per cent more power at high speeds. The slipstream-back cars, in general, had better K-values than the notch-back or trunk-back cars.

What does aerodynamic improvement mean at low speeds ? For the Nash in Fig. 3, air resistance equals rolling resistance at 47 mph, while for the Healey, this is the case at 50 mph. Above these speeds, drag predominates over rolling resistance. For the Vanguard, drag predominates over rolling resistance from 36 mph upwards, but, of course, due allowance should be made for the fact that, relative to the other curves, rolling resistance has been underestimated. At any rate, it can be seen that drag reduction assumes importance well below the safe cruising speed.

The inter-relation between the under-surface of the car and the road surface has already been mentioned, and the importance of a smooth under-surface should be realised.

Tests have been described on a Mercedes-Benz model[12,13] with and without under-shield, and the test points referred to in reference 12 are included in Fig. 3. These tests show an exaggerated saving due to the under-shield, which amounts to 12 per cent. This is rather contradicted both by Professor Lay[3] and the Nash tests[9], in which drag reduction was only of the order of 6 per cent.

(To be concluded)

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CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

BEARINGS

Radial Clearance as a Determining Factor of the Load-Carrying Capacity of Ball and Roller Bearings

By H. PERRET. (From *Werkstatt und Betrieb, Germany*, Vol. 83, No. 4, pp. 131-34, 6 illustrations.)

RADIAL clearances in ball and roller bearings vary considerably with the type of fit employed. This affects the load distribution over the bearing elements (balls or rollers) and hence also the life expectation of the bearing.

A geometrical analysis is given of the load distribution for different clearances, taking into account the elastic deformation suffered by the races. The analysis shows that the specific stresses on the bearing elements increase, in general, with increasing radial clearance. Examples are given to illustrate the wide range of the total radial clearances occurring with the use of standard tolerances on shaft, housing and bearings.

Sets of curves showing the relation between specific loads and radial clearance are given for a typical ball and roller bearing. The curves also give the load distribution over the bearing elements and show that the rise in maximum stress in the load plane, with increasing clearances, is more marked with roller bearings, due to a lesser elastic deformation of the rollers. It is shown that an increase in radial clearances from 0 to 60 microns produces a 24 per cent stress increase in ball bearings and a 47 per cent stress increase in roller bearings. In terms of life expectation, the extreme values give a ratio of 1/1·9 for ball bearings and 1/3·5 for roller bearings.

BLAST FURNACE PRACTICE

Theoretical Considerations in the Operation of Iron Blast Furnaces with Cold Oxygen Carbon-Dioxide Blast

By W. BLELOCH. (From *Journal of the Chemical Metallurgical and Mining Society of South Africa*, Vol. 50, No. 11, May, 1950, pp. 255-292, 10 illustrations, 24 tables.)

THE systems iron-carbon-oxygen and carbon-oxygen are discussed in order to assess the feasibility of the use of a cold or regenerated blast composed to the extent of not less than 95 per cent by weight of oxygen and carbon-dioxide, for operation of iron blast furnaces with coke or anthracite. Such an oxygen and carbon-dioxide blast is referred to as " carbonated blast " and its action is based mainly on the reversal of the reaction $C + CO_2 \rightleftarrows 2\,CO$ in the stack.

The calculation and assessment of performance are based partly upon the free energy-temperature relationship of the oxidation and reduction reactions involved, from which limiting conditions may be computed, and partly upon the data of established haematite smelting practice at high top pressure. The discussion is concerned essentially with the reduction of the oxides of iron to pig iron, as this is considered to be the most important industrial application of carbonated blast. Reduction of other elements such as chromium and vanadium is also considered.

The assessment of the advantages to be gained by the use of cold or regenerated carbonated blast is not treated rigorously from first principles because the blast furnace process is so complex as to prohibit such treatment. The assessment is put forward as an engineering probability based upon well-founded physical and chemical data and principles and upon data of established iron blast furnace practice.

Quantitative data are set out at considerable length and throughout the discussion there is emphasised the crucial importance of carbon deposition through break-down of carbon monoxide in the furnace stack, and of obtaining the highest possible partial pressure of carbon monoxide in the upper bosh and stack of the furnace. The importance of this process for the reduction of haematite with anthracite is discussed and example of estimated capital and working costs compared with normal haematite practice is set out.

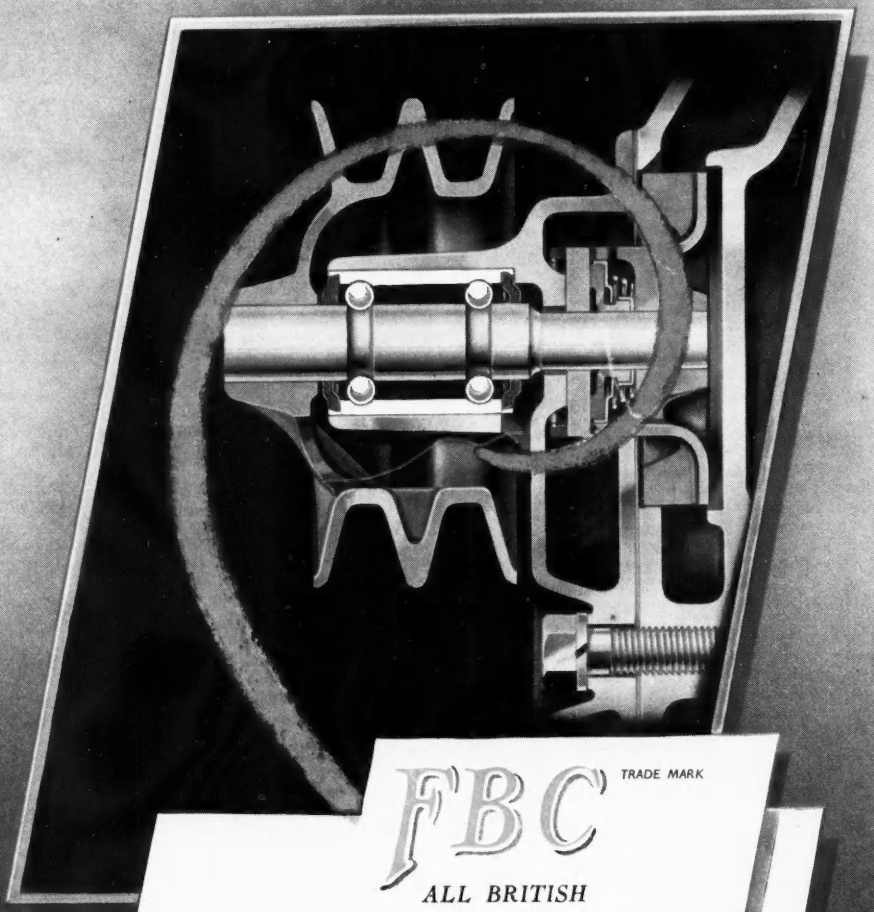
From the consideration of the thermodynamics of the reduction of iron oxides by hydrogen as set out in the text it is concluded that the moisture content of the carbonated blast, the burden, and the coke or other fuel should be suppressed to the minimum attainable in economic operation.

ELECTRICAL ENGINEERING

Electric Properties of Titanium Dioxide

By YA. M. KSENDSOV. (From *Journal of Technical Physics*, Vol. 20, No. 1, 1950, pp. 117-128, 8 illustrations.)

THE ever increasing technical importance of titanium dioxide makes it imperative to obtain reliable data about its electrical properties. The problem is complicated by the difficulty of obtaining pure specimens of TiO_2, because the commercial product mostly investigated until now contains appreciable admixtures of SiO_2, Fe_2O_3, Al_2O_3, MgO, etc. By a carefully studied and conducted process, chemically pure TiO_2 was obtained, in powder form, and the temperature frequency relation of its dielectric constant, conductivity and dielectric losses was established. As control tests, the same measurements were made on commercial TiO_2. The influence of a weakly oxidising atmosphere during the process of fritting the specimens was also investigated. Abnormally high values of the dielectric constant (about 93) at audio-frequencies, increasing with temperature, distinguish pure TiO_2 from the commercial product and from natural rutile. The frequency dependence of the dielectric constant of technical TiO_2 at high temperatures is insignificant. The dielectric losses, which increase with temperature in the case of the commercial product, decrease at audio-frequencies in the case of the pure substance. The frequency dependence of the losses also has a different character in both cases. In the case of the pure product, they rise in the frequency range under investigation. The character of the temperature dependence of ϵ (dielectric constant) and $\tan\delta$ (dielectric loss angle) in the case of pure TiO_2 is best shown by a comparison with $TiO_2 + 0{\cdot}652\ ZrO_2$. The curves of $\tan\delta$ have a distinct maximum, and at the same temperature the dielectric constant has a point of inflection. With increasing frequency, the maximum of $\tan\delta$ shifts towards higher temperatures and becomes less marked, to disappear finally at a frequency of 100 kcps. When the specimen



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is annealed in a weakly or more strongly oxidising atmosphere, the TiO_2 acquires an oxygen excess, and the polycrystalline specimens obtained show large crystals surrounded by inter-crystalline layers. The conclusion drawn is that the distribution of the oxygen is non-uniform, and this leads to the dielectric inhomogeneity observed. A mathematical theory of the inhomogeneity has been evolved and agrees closely with the experimental results.

GAS TURBINES

Approximate Calculation of the Temperature Distribution in Gas Turbine Discs and Blades

By D. SOCHAT. (From *Association Technique Maritime et Aéronautique, France*—Session, 1950, 27 pages, 8 illustrations.)

IN order to calculate the thermal stresses in gas turbine discs, we must know the temperature at any point of the disc. This temperature distribution can be calculated approximately, if the blades are imagined to be replaced by strips of constant cross-section, and the disc by a number of concentric rings of constant width. A radial heat flow from the blades towards the axis is assumed, so that the centre plane of the disc, normal to the axis, becomes a plane of symmetry, and all the points situated on a concentric cylindrical surface have the same temperature. The material is assumed to be isotropic, and the coefficients of conduction and convection are constant, at least within each section of the disc and blades. Gas of constant high temperature throughout is assumed to flow through the blade channels, whilst the disc is cooled by compressed air admitted to the sides of the disc and rotating at one-third the speed of the disc, this figure being based on actual test experience. The formulae are derived from the ordinary theory of heat transmission and, since a fairly rough subdivision is quite sufficient, their evaluation is not too complicated, though it involves Bessel functions.

Numerical interpretation of the results shows that while the blade tip is hottest, the temperature drops, first slowly, then more rapidly towards the root of the blade. The temperature drop from the disc periphery towards the centre is very pronounced and the temperature of the surrounding air is reached in an exponential curve. Illustrative theoretical data are given for the following special example: disc diameter 43·5 in., blade length above disc periphery 1·83 in., turbine speed 4500 rpm, gas temperature 650 C, speed of gas flow 620 fps, air temperature 20 C, air pressure 36 psi. The blades are calculated without any subdivision; the disc is divided into three concentric sections. The temperature is then found to drop from 650 C at the tip to about 500 C at the root of the blades, and the temperature of the surrounding air is already nearly reached at a disc diameter of about 28 in. In these calculations, the temperature of the air has been assumed to remain constant, but quite similar results are obtained if a certain amount of heating of the surrounding air is taken into account.

PUMPS

Seals for Rotating Shafts

By E. F. BOON. (From *De Ingenieur, Holland*, Vol. 62, No. 29, July 21, 1950, pp. Ch. 43-50, 19 illustrations.)

MOST manufacturers of pumps state that a stuffing box should leak a little to take care of lubrication and cooling of the packing. However, the development of the mechanical seal shows clearly that a tight seal is possible. Various factors leading to a tight seal with a normal stuffing box are described, such as perfectly round and smooth shafts, elastic and non-permeable packing material, pressure of packing on shaft higher than pressure in pump, and minimum radial movement of the shaft. A very precise assembly of the packing rings is necessary to obtain a tight seal. This is possible with special tools, drawings of which are shown. Special designs to cope with excessive radial movement of the shaft are described.

WELDING

Cracking of Welded Light-Alloy Structures

By M. HOLLARD. (From *Revue de L'Aluminium, France*, No. 166, May, 1950, pp. 175-182, 17 illustrations.)

CRACKS appear in welds when the metal is prevented from contracting freely during cooling. The tendency to cracking can be diminished by proper design and welding, as well as by the choice of materials showing an inherent resistance to cracking. Such materials for light-alloy structures have been investigated by means of the tests described in the present article. Two light-metal strips, 0·2 in. thick, are rigidly bolted to a heavy base, their widths being reduced near the point where their ends meet. A gap of 5·64 inch is left between the ends of the cold strips, so that they nearly touch when heated to welding temperature. Fifteen seconds after the weld is completed, the specimen together with the base is quenched in water. The test results are classified according to the number and severity of cracks appearing in the welded strip after the quench. Several hundred different light alloys were tested in this manner, the welding rod (0·16 in. diameter) for each being made from the same billet as the parent strip. The test results are evaluated in curves giving the degree of cracking as a function of the several alloying elements.

(a) *Duralinox Alloys Type A-G (Al-Mg Alloys plus Admixtures).*

A certain critical Mg percentage gives the best results. Above and below that percentage, the crack resistance drops. Some of the best materials are: 3·0 Mg, remainder Al; 1·5 Mg, 0·4 Mn, 0·2 Fe, 0·2 Si, remainder Al; or 1·5 Mg, 0·4 Mn, 0·3 Fe, 0·6 Si, remainder Al; moreover, a number of curves show how the percentages can be varied for equally good results.

(b) *Almasilium Alloys, Type A-SG (Al-Si Alloys plus Admixtures).*

Crack-resistant alloys must have about 1·5 per cent Si content. Alloys with 1 per cent Si or less are very prone to cracking. A good material is:—1·5 Si, 1 Mg, 0·2 Fe, remainder Al.

(c) *Duralumin Alloys, Type A-U4G.*

These alloys are prone to cracking and should be avoided. Furthermore, welding destroys the high qualities attained by heat treatment, so that the assembly must be heat-treated after welding. Nevertheless, the mechanical properties suffer from the initial cracks originating during welding even without constraint. Additions of 0·25 Ti and 0·1 Be, however, greatly improve the welding qualities of duralumin. If no constraint is imposed during welding, these alloys will not show any cracks. Even if the plates are of ordinary duralumin and only the welding rods alloyed with 0·1 Be and 0·25 Ti, the crack resistance will be found to have improved.

It is known that cracks may originate at high temperatures, above the solidus line. This occurs mostly in hypo-eutectic materials where, during cooling, the solid solution-plus-liquid mixture cannot maintain cohesion during shrinkage. The cracks may be micro-cracks at

(*Concluded on page* 284)

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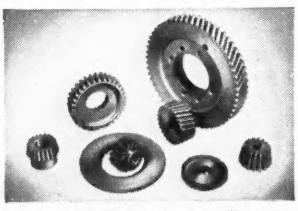

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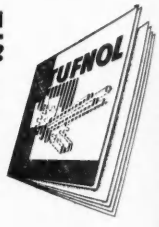

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NEWS OF THE MONTH

PERSONAL

Mr. F. W. Bauer, A.M.I.Mech.E., M.Inst.F., has been elected a director of Bouellat Engineering Ltd., 167 Millbank, London, S.W.1.

Mr. Leslie A. Boobyer has been appointed London sales manager of Lang Pneumatics Ltd., Victory Works, Wolverhampton. His address is 3 River Avenue, London, N.13. Tel.: Palmers Green 5848.

Major F. A. Bumpus has been appointed acting managing director of Blackburn and General Aircraft Ltd.

Mr. T. B. Colman has been appointed works manager of the Grantham Works of Ruston & Hornsby Ltd., Lincoln. **Mr. L. Ingall** has been appointed home sales manager.

Professor W. E. Curtis, F.R.S., D.Sc.(Lond.), A.R.C.S., D.I.C., has been elected President of the Institute of Physics, 47 Belgrave Square, London, S.W.1. **Professor E. G. Cox, D.Sc., F.R.I.C.,** has been appointed vice-president, and **Dr. F. P. Bowden, F.R.S.,** and **Mr. G. R. Noakes** have been elected to the Board. Mr. E. R. Davies and Dr. D. P. Dudding have been re-elected honorary treasurer and honorary secretary, respectively. **Professor H. W. Thompson, F.R.S., Ph.D., B.Sc.,** has been elected to the Board as the representative of the Faraday Society.

Mr. D. G. Denoon, joint publicity manager of British Insulated Callender's Cables Ltd., has been elected chairman of the BEAMA publicity committee.

Mr. G. J. Dickins has been appointed principal assistant to the development officer of London Transport.

Mr. Robert F. Fryars has been re-elected chairman of the British Transport Vehicle Manufacturers' Association.

Mr. K. E. Gerrard has been elected Federal President of the Australian Institute of Metals.

Sir Stanley V. Goodall, K.C.B., O.B.E., has been elected vice-president of the British Welding Research Association, on relinquishing the chairmanship of the Council. **Sir Charles S. Lillicrap, K.C.B.,** has been elected chairman of the Council.

Mr. H. S. Holbrook, B.Sc., M.I.E.E., Fel.A.I.E.E., relinquished the managership of the Transformer Engineering Department of The British Thomson-Houston Co., Ltd., on being appointed consulting engineer on transformers. **Mr. K. W. McBain, M.I.Mech.E., M.I.E.E., Mem.A.I.E.E.,** has been appointed manager of the Department.

Lieutenant Colonel J. P. Hunt, managing director of the Hallamshire Steel & File Co., Ltd., Sheffield, has been elected Chairman of the National Association of Rolled and Re-Rolled Steel Producers.

Mr. Trevor Jenkins has been appointed chief engineer of Guest Keen Baldwins Iron and Steel Co., Ltd.

Mr. George Jendrassik, M.I.Mech.E., has been appointed consulting engineer to Power Jets (Research and Development) Ltd., 25 Green Street, London, W.1.

Mr. T. R. Middleton, B.Sc.(Sheff.), F.I.M., has been appointed a special director of the English Steel Corporation Ltd., Vickers Works, Sheffield.

Mr. F. R. Moberly, secretary of Richardsons Westgarth & Co., Ltd., has been elected to the board of directors.

Mr. J. H. M. A. Reid, B.Sc.(Lond.), research metallurgist of I.C.I. Ltd., Metals Division, Swansea, has been transferred to the technical sales department at Witton, Birmingham.

Mr. W. J. S. Roberts, B.Sc., F.I.M., has been appointed chief metallurgist at the new cold reduction plant and tinplate works at Trostre, of the Steel Company of Wales Ltd.

Mr. Peter Scott has been appointed publicity manager of The English Electric Co., Ltd.

Dr. Charles Sykes, F.R.S., F.Inst.P., director of research of the Brown-Firth Research Laboratories, has retired from the chairmanship of the metallurgy divisional panel of the British Iron and Steel Research Association, 11 Park Lane, London, W.1, and has been succeeded by **Mr. W. Barr,** chief metallurgist of Colvilles Ltd. **Mr. W. C. Bell,** joint director of research of Stewarts and Lloyds Ltd., has been elected chairman of the Association's iron-making divisional panel, in succession to **Mr. G. H. Johnson,** who will be acting as deputy chairman.

Mr. R. T. B. Wynn, C.B.E., M.A., M.I.E.E., has been appointed deputy chief engineer, with responsibility for the general control and direction of all engineering departments of the British Broadcasting Corporation, Portland Place, London, W.1. **Mr. H. L. Kirke, C.B.E., M.I.E.E.,** has been appointed assistant chief engineer, with responsibility for the technical work of the research, planning and installations, designs and equipment departments; **Mr. W. Proctor Wilson, C.B.E., B.Sc., M.I.E.E.,** head of the research department; and **Mr. E. C. Drewe, M.I.E.E.,** assistant head of the research department.

BUSINESS NOTES

The B.S.A. Tools Group of Companies, comprising B. G. Machinery Ltd. (Reconditioned Machine Tools); B.S.A. Tools Ltd. (Machine and Small Tools); Burton, Griffiths & Co., Ltd. (Sole Agents for the Group and Factors in the United Kingdom); Cardiff Foundry & Engineering Co. (1947) Ltd. (Engineers' Pattern Makers, Ironfounders and Repetition Casters); Index Automatic Machine Co., Ltd. (Automatic Screw Machines) and Leo. C. Steinle Ltd. (Thread Generators and Tapping Machines) have opened on August 1st, their new London Office, at 93 Albert Embankment, London, S.E.11. Tel. Nos.: Machine Tools—Reliance 2891 (4 lines); Small Tools—Reliance 2891 (6 lines).
The Leeds Office address of the B.S.A. Tools Group is now 9 Mill Hill, Boar Lane, Leeds. Tel. No.: Leeds 22542.

Rotoplunge Pump Co., Ltd., of 58, Victoria Street, London, S.W.1, has been acquired by Monitor Engineering & Oil Appliances Ltd., of Stechford, Birmingham, a Company of the Parkinson & Cowan Group.

Under new ownership it is intended to increase substantially the available productive capacity and to extend further the range of pumps which have so long been associated with the name of Rotoplunge.

As from August 1st the Rotoplunge Pump Company's address is Flaxley Road, Stechford, Birmingham, 9. Telephone No.: Stechford 2253.

F. J. Edwards Ltd., 359-361 Euston Road, London, N.W.1, announce the appointment to the Board of the following staff executives:—Mr. Ronald A. Johnson, Jnr., to director; Mr. G. M. Hayward, to technical director; Mr. S. Plastock, to machine tool director, and Mr. C. Dalley, to works director.

Mr. Paul Weeks Litchfield, dean of America's rubber industry, who started his business career as a $9-a-week engineer and rose to chairman of the board of the Goodyear Tire & Rubber Company, celebrated the completion of 50 years of continuous service with the firm.

The 500,000,000th pneumatic motor vehicle tyre was produced by Goodyear at Akron, Ohio, to commemorate Mr. Litchfield's 50th anniversary with the Company.

Mr. Selden T. Williams, vice-president of the Scovill Manufacturing Co., Inc., has been elected President of its subsidiary company, A. Schrader's Son, Inc. As general manager of Schraders' since 1944, Mr. Williams has been responsible for the manufacture of tyre valves, gauges and industrial air equipment at the Company's plants at Brooklyn, N.Y., Birmingham, and Toronto, Ont., Canada.

YOUR PROBLEM is our business!

* RECLAIMING MACHINE SHOP ERRORS AND WEAR.
* HARDENING WITHOUT DISTORTION.

Specify— BRAILEY (Regd.)

FOR HARD CHROMIUM AND HEAVY NICKEL ELECTRO-DEPOSITION.

* Our 32-page booklet covers many applications of the process and will be sent on written request to responsible enquirers. Our technical representative will be pleased to call.

BRAILEY Electroplaters Ltd
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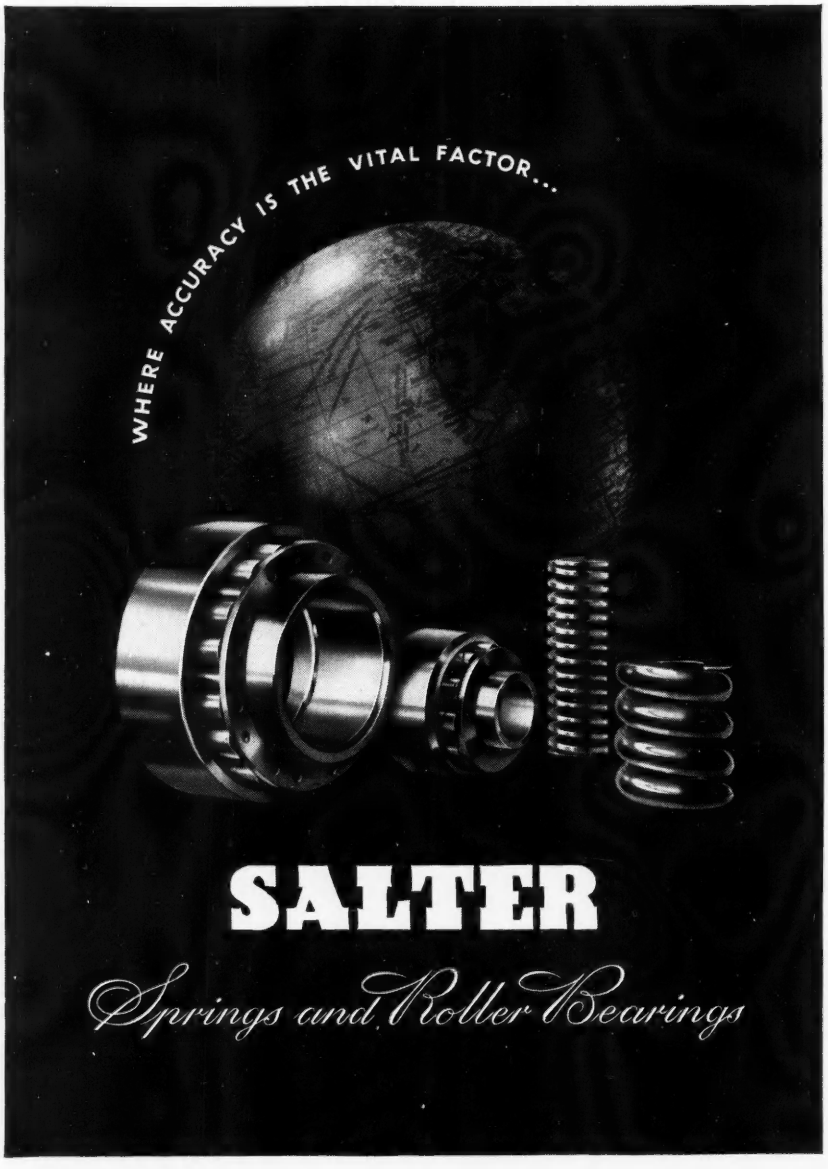


Geo. Salter & Co. Ltd., West Bromwich

M-W.157

Albright & Wilson Limited, who for the past four years have acted as the distributors of silicones in Great Britain for the Dow Corning Corporation of America, announce their intention to commence manufacture of silicones in this country.

Silicone products are available in many forms, including :—

COMPOUNDS.—Heat-stable, water-repellent insulating materials for sealing high tension ignition systems, and high frequency equipment. Mould release agents and foam inhibitors.

GREASES.—Special lubricants for valves and bearings operating at extremely high and low temperatures.

FLUIDS.—Heat-stable, inert liquids for use as damping and hydraulic fluids, mould release agents, heat transfer media, diffusion pump oils, high temperature lubricants and for waterproofing insulator surfaces.

RESINS AND VARNISHES.—Heat-resistant waterproof materials for use in electrical insulation, and as bonding agents and protective coatings.

SILASTIC RUBBER.—A silicone rubber, flexible at — 110° F and at 500° F. Available in grades suitable for moulding, extruding, coating, laminating and caulking.

The demand for silicones in all branches of industry has grown considerably since their introduction in the commercial field, and when manufacture begins it will be possible to meet the requirements of many firms whose allocation has hitherto been restricted owing to supply difficulties.

A. A. Jones & Shipman Ltd., Leicester, have acquired the rights to manufacture, and the exclusive rights of sale in the British Commonwealth of Nations, with the exception of Canada, the whole range of products manufactured by the Micromatic Hone Corporation, Detroit.

The programme includes the production of Micro-mold abrasives, the mounted and unmounted abrasives stones used in the brake type honing tools, the full range of honing tools and machines varying in capacity from 6 mm to approximately 4 in. diameter.

Remington's Progress in Britain. " The American output per man hour has been equalled, in some instances, by our operatives," state Remington Rand in a report on their Hillington (Glasgow) factory. Opened only ten months ago, this factory now employs over 2,000 people. The report reveals that there are as many as 2,850 parts in a standard typewriter—more than in a motor car. When in full swing the factory will be making one million parts per day. The British tooling-up is now completed and the aim is to reach 5,000 Standard typewriters and 2,000 Portable typewriters a month by December, giving Hillington the largest typewriter output outside the U.S.A.

" We have put a million pounds sterling worth of plant and tools into this one project, only one of four we have in Britain," the Company state. " We are in the export drive up to our necks, but we look forward to the day when ample supplies of typewriters will be available in the home market."

NEW COMPRESSOR UNIT FOR JET AIRCRAFT.

The Hymatic Engineering Co., Ltd., has been co-operating with The English Electric Co., Ltd., in the development of a new electrically driven compressor unit for use on jet aircraft where no direct mechanical drive from the gas turbine installation is available.

A considerable saving in weight has been effected by dispensing with the usual heavy engine-driven gearbox and by providing instead a drive to a large electric generator capable of powering the aircraft's auxiliary services. Despite the additional electric motors required by this system the weight reduction remains appreciable.

Actuated by this generator, the new unit consists of an English Electric 0·9 hp, 9,500 rpm, 24 v. motor which drives a standard Hymatic compressor for 450 psi or for 600 psi through a reduction gearbox with a ratio of 7·25 to 1. A cooling fan is fitted at the other end of the motor's armature shaft.

The compressor provides generating pressures of up to 600 psi, at which point it delivers 1·25 cu ft of free air per minute.

Lubrication for the compressor is of the dry sump type and is provided by a forced oil supply from pumps and tank housed in the reduction gearbox. Current drawn by the unit ranges from 30 amps at zero pressure to 44 amps at 600 psi.

A further series of electrically driven units providing pressures of 1,000 psi is now being developed and these will be available with an alternative AC motor operating on a 200 v., 400 cycles three-phase supply.

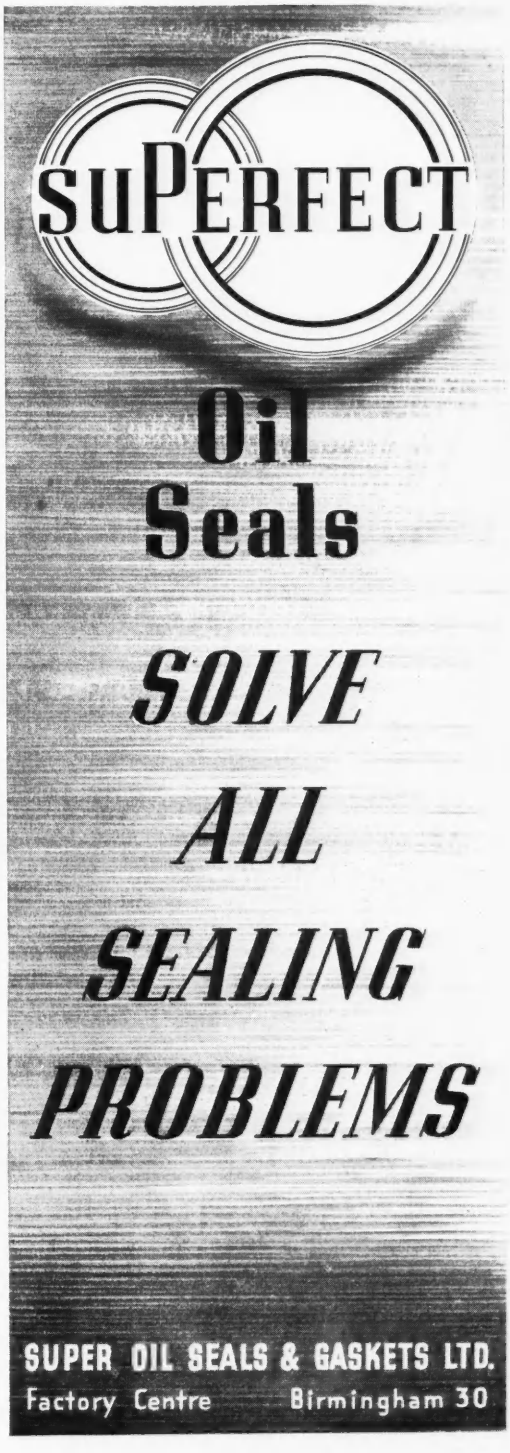
INTERNATIONAL MOTOR EXHIBITIONS.

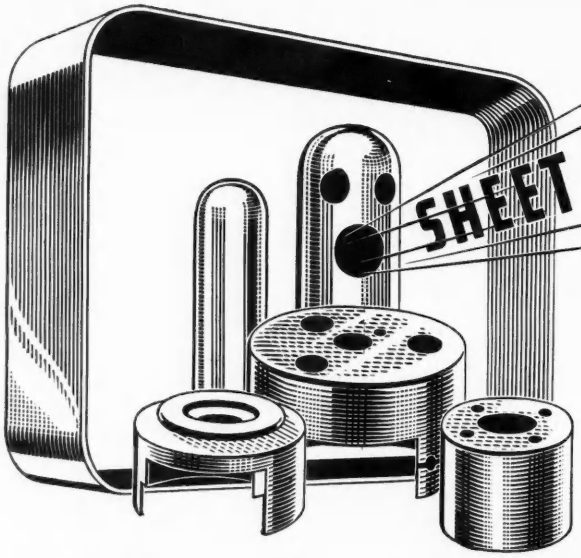
The Society of Motor Manufacturers and Traders Ltd., 148 Piccadilly, London, W.1, has issued more than 12,000 invitations to potential overseas buyers for the 15th Commercial Motor Transport Exhibition to be held from September 22 to 30, and for the 35th International Motor Exhibition to be held from October 18 to 28. The Commercial Motor Transport Exhibition will cover heavy, medium and light vehicles for all passenger, goods and general purposes. Constructional, maintenance and repair materials, tyres, accessories and components will also be exhibited. The International Motor Exhibition will include exhibits of the world's leading car manufacturers. Motor boats, marine engines, trailers, transport service equipment, etc., will also be on show.

THE MANCHESTER FUEL EFFICIENCY EXHIBITION

The Minister of Fuel and Power, Mr. Philip Noel-Baker, has accepted an invitation to open the " Fuel Efficiency in Industry and Home " Exhibition to be held at the City Hall, Manchester, from 22nd November to 2nd December, 1950.

The exhibition, which is being held under the auspices of the National Smoke Abatement Society, will feature plant and appliances that promote the better and more economical use of fuel of every kind, and is being planned to give full prominence to both the industrial and the domestic aspects.





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For sheet metal pressings, drawn envelopes, drawn cups, better get in touch with G. G. L. Our close-tolerance mass production methods keep costs low without sacrificing accuracy.

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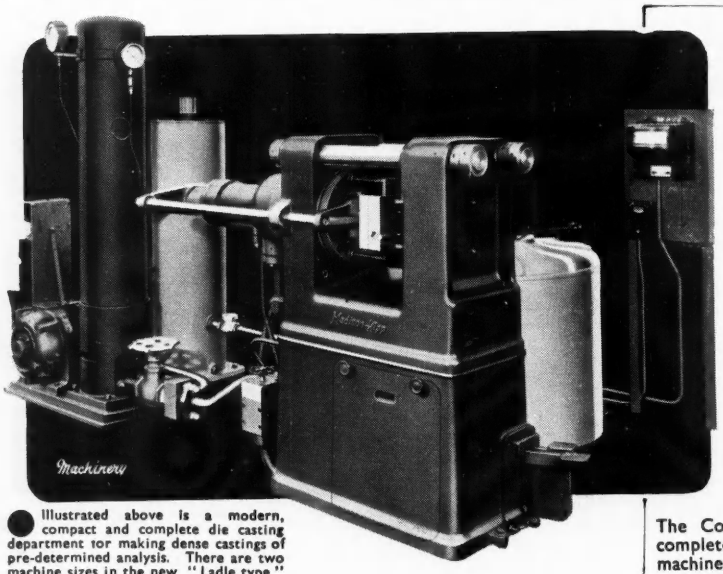

Illustrated above is a modern, compact and complete die casting department for making dense castings of pre-determined analysis. There are two machine sizes in the new "Ladle type" 400 series for die casting metals that melt at high temperatures—brass, aluminium and magnesium. For zinc, lead and tin alloys which melt at comparatively low temperatures, there are other models of 'Goose-neck type' machines in all sizes.

MADISON-KIPP

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PRESSURE DIE-CASTING MACHINES

FOR ALUMINIUM, BRASS, AND MAGNESIUM

The Coulthard die casting service is complete. It includes die designs, dies, machines, and die castings in all die casting alloys. You are invited to send blue prints or samples for a complete analysis or to come to Carlisle to see for yourself.

WILLIAM COULTHARD & CO. LTD.

ENGINEERING DIVISION, DURRANHILL RD., CARLISLE.

Boilers, stokers, furnaces, meters, recording instruments, etc., will be exhibited by leading manufacturers. Gas, electricity and coal interests will be represented, and the scientific aspects of fuel utilization will be shown by the Fuel Research Station.

Inquiries for space should be addressed to the Organizers, PROVINCIAL EXHIBITIONS LTD., City Hall, Manchester, 3.

INDUSTRIAL FINISHES EXHIBITION.

The decision to hold the first national exhibition of Industrial Finishes (Earls Court, London, August 30 to September 7, 1950) to be staged in Great Britain, grew out of investigations by the Council of Industrial Design on finish, design, service conditions and cost as they affect consumer goods and machinery.

On the Council's stand at Earls Court examples of good and bad finishing of domestic equipment and machinery will demonstrate the wisdom of consulting the "finishing" specialist from the outset when planning a new product.

Mural displays of the "Avoid" and "Adopt" illustrations in the booklet "Design for Vitreous Enamelling," produced by the Vitreous Enamellers' Association in collaboration with the Council, form a setting for sections of sheet and cast iron correctly and faultily fabricated to receive a vitreous enamel finish. This simple display is intended to help designers and technicians to avoid many costly pitfalls in the early planning stages of production.

Another part of the stand displays the following new and interesting finishes :—

(a) A new high-temperature resisting vitreous enamel finish, demonstrated on a gas cooker grid; shown for the first time in any exhibition.
(b) A high quality, coloured electro-brightening finish on die-castings; shown for the first time.
(c) A new enamel plating shown in a variety of colours on dessert bowls.
(d) A vitreous enamel, free from lead, which can be applied to aluminium; demonstrated by the cover plate of an electric iron.
(e) White and cream coloured anodising.
(f) Speculum plating on tin alloy. This finish, which is particularly resistant to sea water and humidity, will be shown on spoons and forks.

REFRESHER COURSE FOR WORKS AND PLANT ENGINEERS.

A high-level Refresher Course for works and plant engineers over a wide area surrounding Nottingham, will be conducted in the Great Hall of the University of Nottingham. Important Papers, by specialists drawn from Industry, will be presented weekly on Monday evenings for a period of twenty-three weeks, commencing in October, 1950. Each Paper will be followed by intensive discussion.

The Course is based upon a prototype experiment, conducted some months ago at Bristol, the success of which so profoundly impressed observers.

The Nottingham Course has been organised by a Committee, under the Chairmanship of Mr. E. G. Phillips, O.B.E., M.I.Mech.E., M.I.E.E., which includes the Regional Chairmen of the Institution of Mechanical Engineers, the Institution of Electrical Engineers, the Institute of Fuel, the Institution of Heating and Ventilating Engineers, and the Institution of Plant Engineers, in collaboration, with the Regional Advisory Council for Further Education, the Ministry of Fuel and Power, the University of Nottingham, the Nottingham and District Technical College, and the East Midlands Kindred Engineering Societies.

The syllabus is designed not only to increase knowledge but to make more effective use of existing knowledge; to promote the application of advanced techniques in works engineering practice over an extremely wide field. The subjects will be :—

Planned Maintenance; Lubrication; Modern Developments in Mechanical Transmission of Power; Mechanical Handling Plant; Combustion and Steam Raising (three lectures); Steam Utilisation (five lectures); Distribution and Utilisation of Electricity (four lectures); Properties and Treatment of Metals; Heating and Ventilation; Compressed Air Plant (two lectures); Pumping Plant; and Instrumentation of Plant (two lectures).

The fee for the full twenty-three weeks' course will be £3 3s.

The Secretary to the Course, from whom all information can be obtained, is Mr. P. Bailey, Ministry of Fuel and Power, Chalfont Drive, Nottingham.

GAS TURBINE SCHOOL RE-OPENING

BRITAIN'S School of Gas Turbine Technology—the only one of its kind in the world—is re-opening at Farnborough Place, Farnborough, Hampshire, in October.

The School, maintained by Power Jets (Research & Development), Limited, gives instruction in the use of gas turbines in high speed aeroplanes, locomotives, road vehicles, ships, power stations, process power and other industrial applications.

The School has a wide range of gas turbine equipment and engines, including test houses and a jet aircraft on which installation and practical ground instruction is given. On every course actual test-bed runs on shaft-power and jet engines are undertaken by the students themselves.

There will be four different types of courses, one of which is an International course designed specially for overseas engineers.

THE PRESSED METAL INDUSTRY

*PRODUCTIVITY TEAM'S REPORT**

THE Productivity Team from the Pressed Metal Industry has presented a unanimous Report which gives reasons for the greater productivity of press plants in the United States and makes recommendations for increasing productivity in Great Britain. There are over 60 illustrations of American equipment and techniques.

The branch of the industry represented by the Team is mainly occupied with the supply of pressings of various kinds to the motor manufacturing industry. It makes complete all-steel motor car bodies and supplies large quantities of pressings and assemblies for commercial and public service vehicles. The industry also manufactures for the domestic appliance industries refrigerator cabinets, washing machine cabinets and tubs, steel sinks, panels and assemblies for gas and electric cookers. The largest presses are huge machines exerting a pressure of 1,000 tons but those making motor panels are usually of between 250 and 500 tons.

The Report says that American prosperity is based on an expanding economy, more goods produced at lower unit costs leading to greater consumption, increased demand, more production, more wages—a rising spiral.

If a better standard of living is to be achieved in Britain higher productivity at lower costs is imperative. Increased wages not allied to increased productivity can only result in rising prices, reduced demand, reduced production, less wages—a descending spiral.

The American plants visited were found to be much more up-to-date in their equipment. The rate of obsolescence was much faster than in British plants owing, in part, to the American industrialists' insistence on having the latest equipment. The American will not use a machine if he can buy another which will give him a cheaper product. American plant does not receive the careful maintenance given to some British equipment; it is worked to full capacity for a short life and then replaced.

America's larger scale of production lends itself to a far greater degree of mechanical handling. In some instances, where tools are set up for long runs in large presses, fully mechanical hands are fitted to the presses, and the saving of labour is considerable. The Report describes and illustrates the operation of these mechanical hands and suggests that their use in British press plants will be very limited. But in America the lower rate production shops use semi-mechanical handling devices extensively.

The rule in American press plants is that if a mechanical or semi-mechanical device can be installed to replace some physical effort a determined effort is made to obtain it.

In the plants visited by the Team there was no evidence of any trade union restrictive practices which limited earnings. On the side of management when piecework prices have been set there is

*Copies of the Report (price 2/6) can be obtained from the ANGLO-AMERICAN COUNCIL ON PRODUCTIVITY, 21, Tothill Street, London, S.W.1.

"The genie of scientific research might prove to be the ultimate means to better living and permanent peace. No man should withhold his discovery because he fears the use to which it will be put. We must develop the understanding, the maturity, the wisdom, that controls destructive forces and apply the knowledge of science to the better, the common purposes of life—including the abolition of war."—GENERAL OMAR N. BRADLEY, Chairman, U.S. Joint Chiefs of Staff.

WHAT WE DO IS OUR CUSTOMERS' SECRET.... it must not be talked about.. which is all very trying because we would like to give you some idea of the size, character and variety of JIGS and SPECIAL PURPOSE MACHINES we are producing — some are really ingenious. We can tell you though, that we are consulted and employed by many of the foremost Engineering concerns in the Country and so far there has been no requirement with which we have been unable to cope. Why not discuss your next problem with us? WM. C. FRANCIS LTD., Canley, COVENTRY.
Mfs. also of Precision Tools, Prototypes & Welded Constructions.

no restriction on earnings. Nor do the unions apply any restrictions to the up-grading of workers. If an unskilled operator shows an aptitude for his work he can be given a semi-skilled job. The Team found instances of semi-skilled men who were being trained for tool making. After a period of training they were paid the full rates.

The practice of most of the American firms visited is to engage completely unskilled workers and teach them one simple production operation. As they become adept in that job they may be up-graded.

American workers are mass conscious of "the American way of life."

The goods the American worker can buy are limited only by his income. This is an extremely important factor in the high effort generally expended by American workers. The simple fact is that they have more money to spend and more goods on which to spend it. Lower rates of taxation leave the average American worker with more money in his pocket than his British counterpart. The present Income Tax system in Britain has a tendency to restrict output and earnings . . . Into the American worker has been inculcated the desire and definite urge to reach out for those things that only become available to the man who works hard enough to obtain them. He realises that high productivity benefits everyone and responds accordingly.

The Report describes the layout and mass production techniques of American plants and also the methods of materials handling. In all American press plants the greatest emphasis is placed on keeping materials in motion from one operation to another with the minimum of physical effort. It is realised that the flow of materials is the blood stream of business. Manual handling is only permitted when mechanical handling is uneconomical or impossible. The fullest use is made of conveyors of all types—overhead, fixed belt, roller, gravity chutes—and a wide range of specialized equipment.

Liaison between the product designer and the tool designer is very close. The tool designer and the production engineer are brought into the earliest discussions with the component designer and the design is made with a close watch on cost of manufacture and practicability of manufacture. Particular attention is given to the functional parts of the components and parts which are unseen or are of less importance have a correspondingly small amount of attention. The result is a saving in tool and production costs. For tooling, jigging and equipment there is intensive pre-production planning. Greatest attention is given to the reduction of physical effort and, where possible, to the complete elimination of any skilled operation.

In the large press plants a complete range of presses is in use. In the smaller jobbing and batch production plants there is a high degree of specialization and the range of products is smaller than in corresponding British plants. Specialization in product and plant leads to a high degree of efficiency and greater productivity.

Eleven illustrated pages of the Report describe production equipment and methods and as many pages, also illustrated, deal with tool design and manufacture.

A section of the Report on labour conditions says that supervision in the U.S. is on a high level; the supervisor really functions as management at shop floor level; his job is management and he is not encumbered with clerical work.

The Report ascribes the greater productivity of the American pressed metal industry to:

Productivity consciousness at all levels; Efficient utilization of labour; Mechanical and semi-mechanical handling equipment; Line production methods and flexibility of plant layouts; Volume production.

On productivity consciousness the Report says there must be a change of outlook by all concerned—by management, the trade unions, and the workpeople. It must be a combined operation; no one section of the industry alone can produce the results required.

The labour of skilled men and the time of machines should not be wasted by operators doing other jobs than operating machines. Where necessary, service to the operators should be supplied either mechanically or manually. Unnecessary movement and fatigue should be eliminated.

Many devices for handling materials could be cheaply and advantageously introduced in British factories. Even in the smallest British plant productivity could be greatly increased by the use of portable and adjustable conveyors, gravity chutes and hoppers. Hand operated trucks could in almost every case be superseded with great advantage by power-driven trucks.

Line production techniques can be applied to medium size production runs.

Finally the Report recommends the formation of an association of firms in the Pressed Metal Industry for the interchange of ideas and for research into problems of technique and method.

In a letter to *The Engineers' Digest*, Mr. J. M. Phillips, Leader of the Pressed Metal Industry Team, has emphasised the most important contribution which The Sheet and Strip Metal Users' Association, an organisation which is capable of expansion in the directions that the Team would desire, could make to fulfilling the purpose of the Report by taking this recommendation into favourable consideration.

NEW BRITISH AIRCRAFT FOR AIR DISPLAY.

Sixty different types of aircraft are scheduled to appear at the Society of British Aircraft Constructors' Flying Display and Exhibition this year. They will be on show at Farnborough Aerodrome, Hampshire, to guests invited by the Society on September 6th, 7th and 8th. The show will be open to the general public over the weekend, on September 9th and 10th.

Britain's latest Service and civil aircraft will be seen in the flying display which forms part of the show and will take place each afternoon. Some of these have not yet flown but are expected to make their first flights shortly.

It is expected that about one-third of the aircraft on display will be new to this year's show. Few of these will have been seen in public before. The Gloster **Meteor N.F.11** night fighter and the Hawker **P.1081** swept-back wing research aircraft made their debut earlier this summer. Now the public will have an opportunity of seeing other new R.A.F. fighters and naval aircraft. Flights will be made by two new naval torpedo types, the turboprop Fairey **17** and the Blackburn **Y.B.1** and by the piston-engined version of this submarine killer, the Blackburn **Y.A.5.** A new mark of the jet bomber just going into service with the Royal Air Force, the twin-engined English Electric **Canberra B.2,** will make its first public appearance. There will be two new trainer aircraft with side-by-side seating, the Handley Page **H.P.R.2** and the Percival **P.56.**

The largest of this year's new aircraft is the Blackburn **Universal Freighter.** Its fuselage is large enough to hold a single-decker bus. This largest of British freighters will be one of the few four piston-engined aircraft at the display. Another is the de Havilland **Heron** 12-16 seat airliner which made its first flight in May on the day the **Comet** returned from Africa and has already flown for more than 70 hours. Alongside these conventional piston-engined aircraft will be the five-seat Prestwick **Pioneer,** built by Scottish Aviation Ltd., and the first aircraft designed and built in Scotland to go into production. The Pioneer, with its large bat-like flaps, can take off in 80 yards and is expected to go into service in Australia.

S.B.A.C. Exhibitions since the war have placed a special emphasis on the turbine-engined airliner. This year three new gas-turbine-powered aircraft are scheduled to appear.

The first, the Vickers **Tay-Viscount,** was constructed to study the flight characteristics of the Rolls-Royce **Tay** engine. The second is the Avro **Ashton** four-jet experimental aircraft. It has not yet made its first flight but is expected to do so in time for the Display. Six **Ashtons** have been ordered by the Ministry of Supply for research into the characteristics of high-altitude jet flight. The third new airliner, the turboprop **Viscount 700** is the production version of the **Viscount** which will be going into service with British European Airways and British West Indian Airways. The **700** is expected to fly later this month.

The 1950 Display will enable airline officials and technicians to fit the gas-turbine engined airliner into proper perspective. It is now fully recognized—which could not have been said a year ago—that the British industry chose right when it backed the gas turbine for civil aircraft. The turbine-engined airliners on show this year will not all be "brand new" prototypes. They have flown successful proving flights on air routes in Europe and Africa. Already the first few fare-paying passengers have had an opportunity of testing for themselves the smooth, speedy flight of the turbine-engined airliner. It will still be some time before turbojet and turboprop production is in full swing, but they are no longer subject for speculation. Airline operators are already planning either to fit them into their own traffic schedules or else to face the problem of competing against superior speed and comfort with obsolescent aircraft. The S.B.A.C. Show, 1950, will be another significant landmark in the history of aviation.

Classified Advertisements.

The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box number advertisements 1s. extra. Instructions together with remittance must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

WANTED

BACK ISSUES OF THE ENGINEERS' DIGEST Wanted. Copies of the February, 1949, April and May, 1950, issues at 3/6 per copy. Double the original price, 9/- per copy offered for copies of the August, 1940, issue.—Send copies to the SUBSCRIPTION DEPARTMENT, "THE ENGINEERS' DIGEST," 120 Wigmore Street, London, W.1.

WORK WANTED

URGENT PRIORITY CASTINGS.—Well-equipped, old-established Foundry has small part of its capacity immediately available for British engineering firms making for export or other high priorities. Precision aluminium gravity die castings; zinc pressure die castings.—Write or 'phone **Thos. Ashworth & Co., Ltd.** (Dept. A/15/8), Vulcan Works, Burnley, Lancs. (Burnley 3505).

TRANSLATIONS, Abstracts. German, French, by Engineer, long resident abroad. Priest, 50, Sion Road, Bristol, 3.

FOR SALE

NISSEN TYPE HUTS, ex-Government stock, reconditioned and supplied ready for erection. All sizes in 6 ft. multiples. 36 ft. by 16 ft., £65 & £54: 24 ft. by 16 ft., £46 & £38; 72 ft. by 16 ft., £122 & £97; delivered U.K. Plasterboard huts and other buildings. Some 24 ft. span Nissens.—Write, call or telephone, **Universal Supplies (Belvedere) Ltd.,** Dept. 50, Crabtree Manorway, Belvedere, Kent. Telephone No. ERITH 2948.

FOR SALE—NEW 100 K.V.A. ALPHA-HARRIS ALTERNATOR, complete with exciter, type G. 400, voltage 440/220, speed 1,000 r.p.m., 50 cycles, 4 wire, 3 phase. £700.—Norths, 94, Vicar Lane, Leeds. Phone: 26248.

THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *CREEP OF PLASTICS*

In spite of the fact that the creep of rigid plastics, that is to say, their permanent deformation under load, has been studied for the last ten years or so, available data are still far from being exhaustive. The concept of creep is usually associated with the strength of metals at high temperatures, and it is not generally appreciated that two practical aspects of creep at room temperature, namely, sustained stress and continuing deformation, affect a very large variety of moulded parts. Typical examples are fan blades which have to resist centrifugal stress, plastic material surrounding metal inserts under stresses that have arisen from differential contraction, parts under stress from differential water absorption, objects bearing direct load such as coat-hangers and bottle caps screwed tight, and mouldings shrinking under the influence of comparatively high temperature. Under such circumstances, creep may either change tolerances or cause weakening and even failure. The period of stress or deformation may easily extend over several years before ultimate failure occurs, and it is therefore highly desirable that tests to assess creep behaviour should range over fairly extended periods in order to avoid the uncertainty of excessive extrapolation. The results of recent long-time tests yielding reliable data on the maximum stress that can be sustained by certain thermosetting materials for five years should, therefore, prove of great practical value, as should also corresponding data concerning the creep and crazing of thermoplastics for a twelve-months loading period.

● *FLUIDIZATION—A NEW PROCESS TOOL*

The process of fluidization, which has revolutionised catalytic cracking technique in recent years, consists essentially in passing a stream of air or gas from below through a mass of solid particles. If the flow velocity is suitably chosen, the particles will be thrown into a state of extreme agitation and the bed of solids will be expanded by the gas so that each of the particles is freely suspended. There exists a so-called "pseudo-liquid level," above which a comparatively small amount of the finer material, which is carried out of the solid bed, remains in suspension. The phenomenon presents much the same appearance as the surface of a boiling liquid. The intimate contact between individual particles and gas stream produced in this way is now being utilized for the high-speed drying of granular and other substances, and dryers based on this principle are claimed to be extremely compact and efficient. Still another application of fluidization is the transport of grain by compressed air through pipes, and initial tests have shown that wheat, either whole or ground, can be conveyed satisfactorily as a fluid through piping of comparatively small bore. It is considered that the convenience and ease of operation should make this method particularly suitable for farms where grain is to be moved from one building to another. Initial cost of equipment should be quite moderate, it is stated.

● *ENGINE FAILURE PREDICTOR*

The sensitivity of aero-engines to failure as a result of the presence of foreign matter in the lubricating system is well known. Likewise, the sudden appearance of foreign matter in the lubricating oil circuit in service should be immediately heeded as a warning of incipient engine breakdown. In a device that could aptly be termed an "engine failure predictor," developed and employed by the Swedish Air Lines, return oil from the sump passes through six holes in a silver electrode plate. Each hole contains another electrode, which makes contact with the electrode plate should metal fragments of approximately one-tenth millimetre try to pass. This closing of the contacts lights one or more of the six lamps contained in the contact circuits and placed in the pilot's cockpit, thus denoting the presence and approximate concentration of the fragments. This device is operated by alternating current in order to prevent electrolysis of the oil which might accompany direct current.

● *INHIBITION OF FOAMING*

A recent authoritative research report on the inhibition of foaming by novel anti-foaming agents recalls that until now the foaming problem in many industries had to be combatted by the use of traditional remedies. Thus, foaming of boiler water was prevented by adding small amounts of castor oil; the frothing of paper pulp suspensions was prevented by adding various mineral, vegetable or animal oils, and so on. Within the last few years, the synthesis of a num-

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ber of surface-active agents has made possible a superior approach to the problem. A study of those materials that have proved themselves traditionally to be of use has led to the isolation of some of the molecular structural factors that give them the desired properties. With these clues, materials that greatly surpassed the original, traditional remedies were soon synthesized. At the present time, anti-foaming agents are available which are specifically designed for their intended use in industry; and they are so effective that in many applications only a trace quantity such as 10 parts per million is required. Another advantage of these modern anti-foaming agents has also begun to appear. Formerly, the remedy that worked for a certain industrial problem would not work when the conditions were only slightly altered. Modern anti-foaming agents, on the other hand, are capable of wide and useful ranges of application. While it is true that no universal de-foaming agent has yet been made or is likely to appear, the new agents have shown themselves capable of controlling foaming in a greater variety of applications than any of the older materials.

● *PITCH-CHANGING WOOD PROPELLER*

All one-piece wood propellers and metal propellers change their pitch elastically in response to changes in the flight conditions. This change in pitch is not very considerable, but the effect upon propeller performance is very noticeable; and unless special measures are taken, the effect is bad. The idea of utilizing the elastic pitch changes rather than trying to suppress them is, no doubt, attractive. Such a propeller will have to diminish its pitch angle rather than increase it, in response to an increase in the propeller thrust. A surprisingly simple solution to this problem was recently found, and a one-piece wood propeller incorporating this feature will shortly appear on the American market, having passed official tests for powers up to 125 hp. In conventional propellers, the wood fibres extend in the tip-to-tip direction in order to secure maximum strength. The new propeller retains this feature for the hub and for the internal portions of the blades, but in the outer layers the wood fibres are placed diagonally across the tip-to-tip direction. This creates a kind of hinge effect, the blade bending more readily about an axis parallel to the diagonal fibres than about an axis at right angles to the fibres.

● *ADVANCED FOUNDRY METHODS*

The search for a less costly method of producing rotors for steam and gas turbines has resulted in the development of radically new methods for producing castings, including continuous temperature and solidification control by such means as induction heating and brine cooling. The newly developed centripetal or counter-flow process of rotor casting includes the integral and simultaneous casting of blades and shroud, feeding being done from the rim of the revolving casting, and the metal solidifying radially outwards from the centre. This method of casting places the cooler metal with the finer structure in the centre of the wheel. As the periphery of the rotor solidifies last, the centre is placed under compression and the rim in tension. Alloys cast in this way include compositions containing 38 per cent nickel and 18 per cent chromium and others which are not subject to grain size reduction by heat treatment and cannot be truly annealed; hence, the superiority of the controlled grain size wheel cast by the new process. Wheels with cast-in blades can also be produced in this way, and it is significant to note that hollow blades have also been cast by the centripetal process.

● *DUCTILE CHROMIUM SHEET*

A method has been evolved for the production of ductile chromium. When using electrolytic chromium as the raw material, the metal is first ground to less than 65-mesh, and the powder is then treated in a hydride furnace for the purpose of deoxidation. After that the material is ground, briquetted and sintered. The soft ingot is then compressed cold. It is reported that the metal is quite plastic in this state, which is in contrast with the fact that sheets made by hot rolling from the material cannot be bent cold. After re-sintering, the ingot is encased in an iron sheath and compressed hot. The material is then rolled at 800° C and the iron sheath removed. The sheet produced by this method can be easily bent and cut when heated above 500° C. It can also be easily machined and can be cut on a lathe at room temperature. Alloys made with this grade of chromium metal may be of industrial use, since the material is highly corrosion-resistant and is difficult to dissolve in hydrochloric acid. Because of the great softness of the metal above 500° C and its low Rockwell-B hardness at room temperature, it does not appear probable that it will be used to any large extent for highly stressed mechanical parts at room or elevated temperature.

● *NOVEL WEAR-RESISTANT ALUMINIUM COATING*

A novel scratch and wear-resistant hard coating for aluminium developed in America may possibly make this light material eligible for the first time to many applications which today are still being monopolised by steel alloys. The coating is applied to aluminium and aluminium alloys containing less than five per cent copper, either in the wrought or cast form, by an electro-chemical process. This process creates a non-metallic, file-hard, highly heat-refractive surface which is strongly bonded to the base metal. Tests have shown that the new coating provides excellent

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resistance to atmospheric and salt water corrosion, and has proved itself to be far superior to conventional anodised surfaces, it is claimed. The originators of this process announce that the new coating has already been successfully applied to such widely dissimilar items as gears, pinions, surveying instrument parts, turbine impeller blades, hand tools, swivel joints, leading edges of high-speed aerofoils, which are susceptible to wear by the surface attrition of dust and rain, etc. Coating thicknesses range from 0·0001 to 0·006 inch, but for abrasion resistance a coating of 0·002 inch is generally used.

● *CHILLING GRAPHITE MOULDING MIXTURE*

Controlled shrinkage of sand castings can be obtained by directed solidification with the aid of chills, i.e., pieces of cast iron, copper, or aluminium of suitable size and shape placed in the wall of the mould where faster freezing of the metal is desired. Metallic chills are known to possess certain drawbacks, such as the danger of gas release from cast iron chills, the sweating of chills which are not perfectly dry, etc. In a novel process, the high heat conductivity of graphite is imparted to the moulding material by burning an intimate mixture of graphite and clay, crushing it, and running it through the proper sieves. The mixture is made plastic by adding bentonite, some organic binder, and water up to 6 to 10 per cent. This material is used to embody a chilling layer of $\frac{1}{4}$ to $\frac{3}{4}$ inch thickness in the walls of the sand mould where required.

● *INDIRECT CONTACT ACTUATION BY MEASURING INSTRUMENTS*

Direct contact-making for the operation of control circuits can be performed by the pointer of a measuring instrument only if the moving system produces a fairly high torque. In sensitive instruments, the employment of the pointer for this purpose is generally undesirable, since the production of a mechanical effort adversely influences accuracy of indication. These considerations have led to the development of chopper bar type mechanisms, which, however, operate intermittently at fixed time intervals. In another type of instrument, the pointer carries a vane which, when the control value is reached, intercepts a small jet of air normally impinging upon an electrically heated wire and cooling it. This wire forms part of a bridge circuit, which is thrown out of balance and operates a relay when the wire gets hotter owing to the interception of the cooling jet. Other methods which have recently been finding favour rely upon the use of photo-electric cells or upon small capacitance changes produced by the movement of the pointer, which are then electronically amplified. A recent proposal envisages the interception by the pointer vane of the infra-red heat radiated from a heating element upon the temperature-sensitive wire coil forming part of a bridge circuit. Accurate cut-off in this system is secured by the use of semi-elliptical mirrors.

● *NOVEL SAND-BLASTING MACHINE*

In a novel type of sand-blasting machine, the blast action is produced by the employment of a centrifugal throwing wheel with its horizontal shaft revolving peripherally around a vertical spindle. The high speed of the wheel produces a fan action, which is utilized to draw the sand by suction to the wheel, whence it is thrown at high velocity against the surfaces to be cleaned, the workpiece being placed on a revolving table. The sand is returned to an overhead bunker by means of a special lifting tube, without the use of a bucket elevator. The machine is electrically driven and the blasting process is continuous, the sand being automatically freed from foreign matter.

● *ATOMIC GOLF BALL*

An atomic golf ball that cannot get lost was recently demonstrated by an American firm of golf ball makers. Minute quantities of radioactive material embedded under the cover of the ball make it possible for a caddy equipped with a small portable Geiger counter to locate the atomic golf ball even when hidden in dense woods or deep rough. The location of a lost ball can be telegraphed by the Geiger counter in two ways, namely, either by a flashing light on the instrument or by signals which the caddy can hear through headphones. No sale of radioactive golf balls is contemplated at the present time, but in the opinion of the research chief in charge of this development, this application of atomic energy may eventually solve the problem of the lost golf ball. It is stated that the amount of radioactive material inside the ball is too small to involve any danger from radiation.

● *PROBLEMS OF METAL FORMING AND PRESSING*

Problems in the forming and pressing of low-alloy, high-tensile steels have been investigated at the U.S. Mellon Institute. These researches have revealed that circle blank reductions of 65 per cent are entirely feasible when composite dies are employed in drawing. In order to achieve these end-results of large circle reduction, certain prerequisites of chemistry and metallurgy were found to be imperative. Studies have been made by means of a modified Sachs' wedge test and linked with established data by miniature cup testing. It has been demonstrated by experimental pressing that non-ferrous alloys can also be reduced by large amounts if certain chemical and physical requirements are met to develop definite rates of strain hardening.

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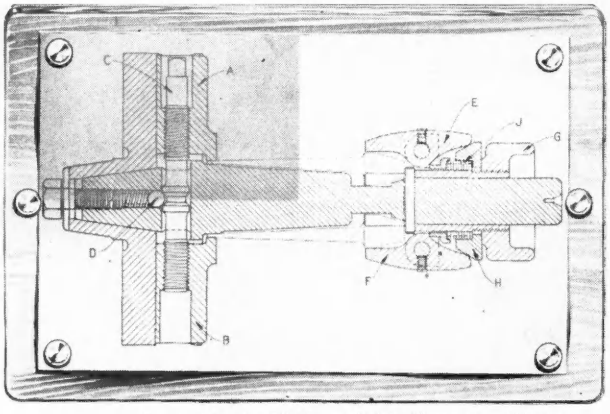

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● *SMALL VIBRATORY BALL MILL*

It frequently happens in laboratory practice or pilot plant operation that small quantities of finely pulverised material must be prepared. In such cases, a new type of ball mill which can be easily constructed may prove of considerable utility. The grinding mechanism of the mill is made of a piece of pipe, closed at the ends and filled with a number of steel balls and small lumps of the material to be ground. The pipe is then shaken in an elliptical trajectory by means of a simple mechanical device. The efficacy of the grinding action will be readily appreciated if it is considered that a single layer of steel balls of 7 mm diameter covering the bottom of a $\frac{3}{4}$ in. pipe will produce 150 mutual impacts (and impacts with the wall) per stroke. By filling 100 balls into the pipe, no fewer than 16,000 impacts per second can be produced in this manner. It is not, therefore, surprising that a pulverised product of 0·1 to 0·5 micron particle size can be obtained in a few minutes of operation.

● *NEW ELECTRIC ROOM HEATER*

A new type of electric room heater consists of an expanded metal grille base mounted on supports which provide a few inches clearance between the base and the floor, so that a flow of air can rise through the heater. In front of the usual type of reflector, glass tubes containing the heating elements of the coiled wire type are placed. The ends of the heat-resistant glass tubes are provided with stainless steel caps serving as contacts. It need hardly be stressed that the glass casing effectively prevents short-circuiting of the coil by accidental contact. The heating coils are made of an alloy containing approximately 60 per cent nickel and 15 per cent chromium, the balance being iron.

● *CORROSION-RESISTANT MOULDED EJECTOR*

Steam jet ejectors for the handling of corrosive vapours represent a special problem. They must be constructed so as to resist the corrosion which would otherwise destroy them. The solution to the problem has been found in the use of a moulded material made from acid-digested asbestos and synthetic resin. This material resists corrosion by hydrochloric, sulphuric, and hydrofluoric acids, wet chlorine, caustic, benzine, and other solutions, including some of the chlorinated aromatic compounds. The material can be readily moulded into the shapes of ejector parts as well as intercondenser sections, and is strong, tough and durable. It is reported that in the case of a chemical plant it was the practice to use ordinary cast iron single-stage ejectors until they were eaten up so badly that they would not work satisfactorily and had to be replaced. Ejectors made of the new material were installed in this plant and after having been in service for more than one year, one of the ejectors was taken apart. The only sign of corrosion noted was that the sharp edge on the nozzle tip had crumbled away a little. The edge of the nozzle was then rounded off and the ejector was again put into service. For conditions requiring somewhat less corrosion resistance, one manufacturer is reported to machine suction chamber, nozzle and diffuser from high-density graphite.

● *ELECTRONIC HAIR REMOVER*

Beauty culture can be said today to represent a major industry, and its engineering problems are, therefore, of some importance. An unusual electronic problem relates to the removal of unwanted body and facial hair. Earlier methods of electrolytic hair removal have been superseded by the application of radio-frequency current by means of a needle electrode owing to the greater speed of the latter process. In the radio-frequency process, removal of the hair is achieved by highly localised heat generation. As the high peak voltages produced by the spark circuit originally employed caused occasional scarring of surrounding tissue, employment of thermionic oscillators was subsequently resorted to. A new machine of this type incorporates an electronic timer, the automatically timed current impulses being initiated by a foot switch which also controls the length of manually timed pulses. This particular unit generates about four watts at five megacycles.

● *SPECIAL SPRAY TECHNIQUES*

In order to eliminate the mist created in the spraying of paints and lacquers when using compressed-air spray pistols, spray plants have been designed to operate without compressed air. In this type of spray equipment, the paint is ejected from the nozzle by hydraulic pressure and the supplementary air movement required is produced by an electrically driven turbo-fan. In a modification of this method, the air is electrically heated. Compressed air operation is also avoided in a device designed to produce velvet-like naps on surfaces. In this plant, the fibre of appropriate length contained in a vessel is stirred in the latter by means of a fan and then ejected upon the glue-covered surface to be provided with the velvet nap. It is claimed that by this means an approximately upright pile is formed, and that production costs with this method are considerably lower than with the electrostatic process.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

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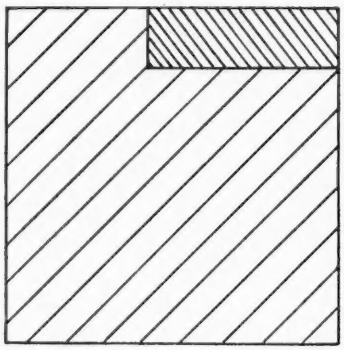

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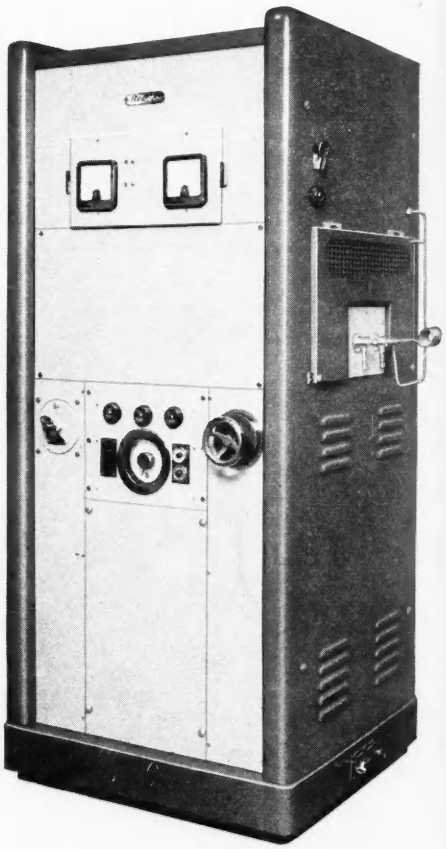

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